

**BIOGRAPHICAL MEMOIRS OF FELLOWS
OF THE
INDIAN NATIONAL SCIENCE ACADEMY**

Volume 5



**INDIAN NATIONAL SCIENCE ACADEMY
NEW DELHI**

BIOGRAPHICAL MEMOIRS OF FELLOWS OF INDIAN NATIONAL SCIENCE ACADEMY

(formerly, National Institute of Sciences of India)

1979

VOLUME 5



INDIAN NATIONAL SCIENCE ACADEMY
Bahadur Shah Zafar Marg, New Delhi

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Published May 1979

Price : Rupees Thirty

PUBLISHED BY DR S.K. DASGUPTA, EXECUTIVE SECRETARY, INDIAN NATIONAL SCIENCE ACADEMY,
BAHADUR SHAH ZAFAR MARG, NEW DELHI-110002 AND PRINTED AT INDRAPRASTHA PRESS (CBT),
NEHRU HOUSE, NEW DELHI-110002.

PREFACE

LYTTON STRACHEY, archpriest of the reaction against the dusty biographical techniques of the nineteenth century aimed at a "*brevity which excludes everything which is redundant and nothing that is significant.*" The current volume of the "*Biographical Memoirs of Fellows of the Indian National Science Academy*," the fifth in the series, is an attempt in this direction.

The memoirs were conceived as a means of providing an authentic account of the inspiring lives and achievements of the past Fellows of the Academy. Unpublished material pertaining to some of the Foundation Fellows was not available for preparing this volume as many of their close associates are no longer living. Much of the valuable information has therefore been lost to posterity.

Included in this volume are biographical sketches of thirteen distinguished Fellows of the Academy, who played a significant part not only in advancing the frontiers of their chosen field but also in establishing a tradition of scientific inquiry in this country.

Professor P. C. Mahalanobis put India on the statistical map of the world, founded the Indian Statistical Institute and also *Sankhya*, the Journal of Statistics. He demonstrated the importance of statistics in planning and was the architect of India's Second Five Year Plan. His close associate Dr. S. N. Roy, noted for his contribution to mathematical statistics, held the Chair of statistics at the University of North Carolina, U.S.A. and is long remembered as an inspiring teacher. Dr. V. G. Panse, another brilliant statistician, was a pioneer in developing statistical methods in agricultural research.

The volume covers three internationally recognized mathematicians (Drs. Ganesh Prasad, T. Vijayaraghavan and S. Minakshisundaram), a keen astronomer (Dr. A. C. Banerji) a highly gifted plant anatomist (Dr. G. P. Majumdar), an outstanding obstetrician and gynaecologist who developed a new type of surgery for cancer of the cervix (Dr. Subodh Mitra), a dynamic pharmaceutical chemist (Dr. U. P. Basu) and a brilliant biochemist who developed many analytical techniques (Dr. K. V. Giri).

It is interesting to reflect upon how the course of events had been strongly influenced by each scientist whose biography is included in this volume. For example, it was the publication of the work of Dr. Rustom Jal Vakil in the British Medical Journal (1949), which brought the use of reserpine—an alkaloid from *Rauvolfia serpentina*, a drug used in ancient Ayurveda medicine—as a tranquilizing agent and in psychiatric therapy into modern medicine.

What would have been the direction and pace of space research activities in India, had not Dr. Vikram Sarabhai, an outstanding Cosmoic Ray scientist, worked ceaselessly to give the country his time and talent?

Reading through the brief life-sketches presented here is an inspiring experience. The lives of these scientists are characterised by their zeal, creative ability, commit-

ment, strength of character, knowledge, wisdom and above all great humility. Here is a glimpse of our scientific heritage in the recent past.

The authors deserve special thanks for their effort which necessitated considerable research. May I express my deep appreciation to several senior Fellows of the Academy, Professor L. S. Kothari and K. N. Saxena (the previous editors) and members of the Editorial staff for their able assistance in bringing out this volume.

Professor B. R. Seshachar, past-President of the Academy has read through all the manuscripts meticulously and has made them press-worthy. I thank him most cordially for the valuable service he has rendered to the Academy in editing the material for this volume.

V. RAMALINGASWAMI
President

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A photograph and an autograph of the subject are printed with each memoir.



J.C. Mahalanobis

PRASANTA CHANDRA MAHALANOBIS

(1893-1972)

Foundation Fellow 1935

MAHALANOBIS ERA IN STATISTICS

THE PROFESSOR, as Prasanta Chandra Mahalanobis was known in India, passed away on 28 June 1972 in a nursing home in South Calcutta three weeks after an abdominal operation. Born on 29 June 1893 he would have completed 79 years on the next day; his last rites were performed on his 79th birthday. At the time of his death he was actively engaged in research, in guiding the work of the Indian Statistical Institute as its Chief Executive, Secretary and Director, and in advising the Government of India on statistical problems as Honorary Statistical Adviser.

In India, statistics was practically unknown in the first quarter of this century. There was no teaching or research in statistics at the Universities, no statistical society and no journal of statistics. Official statistics were collected only as a by-product of the administration. A sudden spurt of statistical activity occurred about 40 years ago, which was to put India, in the course of a few years, in the centre of the statistical map of the world.

The Indian Statistical Institute was founded by Mahalanobis in 1931, with facilities for high level research, training and execution of large-scale project work. *Sankhya*, the Indian Journal of Statistics, was started in 1933. The new technique of estimating acreage and crop yield by random sampling was worked out and applied to jute in Bengal in 1937. The first Indian Statistical Conference was held in 1938. Post-graduate studies in statistics were opened for the first time in India at the Calcutta University in 1941 under the guidance of Mahalanobis. The Indian Science Congress, which had not recognised Statistics as separate discipline for a long time, included it in the section of mathematics in 1942 and created a separate Section for Statistics in 1945. A Central Statistical Unit was established by the Government of India in 1949 with Mahalanobis as Honorary Statistical Adviser to the Cabinet; two years later, the Central Statistical Organisation (CSO) was formed for coordinating all statistical activities of the Government, and soon after, the Department of Statistics was created. Based on the experience gained in Bengal, the National Sample Survey (NSS) was established in 1950 for the collection of socio-economic data through sample surveys covering the entire country, to provide information needed for government policy decisions and for the computation of national income. In 1954, the Prime Minister and the Planning Commission called upon Mahalanobis to initiate studies in planning at the Institute to find ways and means of increasing national income and solving the unemployment problem.

The Indian Statistical Institute was recognised as an institute of national importance and permitted to award degrees in Statistics by a Central Act in 1959.

Training of technicians for statistical quality control started in 1945 at the Indian Statistical Institute. A conference on standardization and quality control was held in 1948, which gave a start to the quality control movement in India. These significant achievements within a short span of time would not have been possible without the indefatigable energy of Mahalanobis.

With his death, the Mahalanobis era in statistics which started in the early twenties ended. Indeed, it will be remembered as the golden period of statistics in India, marked by intensive development of a new technology and its applications for the welfare of mankind.

EARLY LIFE AND EDUCATION

Prasanta Chandra Mahalanobis was born in Calcutta on 29 June 1893 in a well-known family of *Brahmos* (a protestant theist movement within the fold of Hinduism, founded in 1828 by Raja Ram Mohan Roy). He was the eldest of six children, two sons and four daughters. His father, Probodh Chandra was a businessman, and his mother Nirodbashini was a sister of Sir Nilratan Sarkar, the famous physician, educationist and industrialist. Prasanta had his early education in Brahmo Boys' School. Later, he went to the Presidency College and obtained his B.Sc. degree with honours in Physics in 1912. Soon after, he left for Cambridge, U.K. for higher studies, where he took Part I of the Mathematics Tripos in 1914 and Part II of Physics Tripos in 1915. He was awarded a senior scholarship by the King's College, Cambridge; his intention was to work with the famous experimental physicist, C.T.R. Wilson, at the Cavendish Laboratory after spending a short vacation in India. But this did not materialise.

Mahalanobis married Nirmal Kumari on 27th February 1923. Rani, as Nirmal Kumari came to be known to friends of Mahalanobis, was a devoted wife. In the true Indian tradition she took up all the responsibilities of running the household, looked after the continuous stream of guests they had, relieved him of all the worries associated with his busy life, and made his life complete. She was constantly with the Professor throughout his life, and accompanied him on his frequent tours abroad and within the country.

PHENOMENAL ACTIVITY

Mahalanobis was offered a teaching position in the Physics Department of the Presidency College in Calcutta soon after his return from Cambridge. He joined the Indian Educational Service (IES) in 1915, held the post of Professor of Physics and later became Principal, Presidency College, from which he retired in 1948. During his life time he held several distinguished positions, several of them simultaneously. He was the chief executive of the Indian Statistical Institute, Calcutta, continuously since the founding of the Institute in 1931, Honorary Statistical Adviser to the Government of India since 1949; and was associated with the Plan-

ning Commission (1953-67). He also served as a Meteorologist in Calcutta (1922-26), General Secretary of Vishva Bharati (1921-31), the University founded by Rabindranath Tagore, Head of the Department of Statistics of the Calcutta University (1941-45) and Statistical Adviser to the Government of Bengal (1945-48). He was Member of U.N. Statistical Commission since 1946 and its Chairman (1954-58), General Secretary of the Indian Science Congress (1945-48) and Treasurer (1952-55), President of the Indian National Science Academy (1957-58) and Editor of *Sankhya*, the Indian Journal of Statistics, since its founding in 1933.

His work apart, the Professor was in the mainstream of Bengal's social, cultural and intellectual movements. He tried to reform the Brahmo Samaj by arguing against some of its rigid tenets. He wrote a number of literary and Philosophical articles in Bengali and English. He was associated with Rabindranath Tagore and edited the '*Quarterly of Vishva Bharati*'; he was acknowledged as an authority on the literary works of Tagore.

With all these activities, he could spend long hours arguing or discussing with his colleagues giving instructions to engineers and administrators, examining legal matters connected with the ISI, working out programmes for numerous foreign visitors to the ISI, and in between, giving time to his pet cat with whom he appeared to be able to communicate.

He was mentally alert and physically active throughout his life. Even after he was admitted to the nursing home in Calcutta he was constantly thinking of the new statistical tool he was developing, 'Fractile Graphical Analysis', and discussing with the present author some theories he had developed. He baffled the doctors by putting up a valiant battle for three long weeks after an operation before death overtook him.

CONTRIBUTIONS TO STATISTICS

While in Cambridge, Mahalanobis accidentally came across *Biometrika*, edited by Karl Pearson, in the King's College Library. He got so interested in the Journal that he bought a complete set of volumes and brought them to India. He soon discovered that statistics was a new discipline capable of wide application. In India, he tried to look for problems where he could apply statistics. Fortunately, he found some extremely interesting ones in Meteorology and Anthropology, and this marked a turning point in his career from a physicist to a statistician.

The Indian Statistical Institute

Genesis—The idea of starting the Indian Statistical Institute was conceived by Professor Mahalanobis and a group of young men who had gathered round him in the twenties (1920-31). There was already a workshop, in what came to be known as the Statistical Laboratory, located in the room of Mahalanobis, then Professor of Physics at the Presidency College, Calcutta. A public meeting, called over the signatures of Pramatha Nath Banerji (Minto Professor of Economics), Nikhil Ranjan Sen (Khaira Professor of Applied Mathematics) and Prasantha Chandra Mahalanobis was held on 17 December 1931, with the late Sir R.N. Mukherji in

the Chair. This meeting adopted a resolution which led to the establishment of the Indian Statistical Institute which was registered on 28 April 1932 as a non-profit distributing learned society under the Societies Registration Act XXI of 1860.

Phenomenal Growth—In the beginning, the Institute was located in the Physics Department of the Presidency College. During the fifties the present premises of the Institute on Barrackpore Trunk Road was built. At the time of the Professor's death, the Institute at Calcutta and its branches at Bangalore, Baroda, Bombay, Delhi, Ernakulam, Giridih, Madras and Trivandrum had a total staff of over 2000, and an annual budget of about twenty million rupees. The phenomenal development of the Institute was mainly due to the individual efforts and imaginative planning by Mahalanobis. Other factors contributing towards his success were the great encouragement and support he received from two men of vision, Jawaharlal Nehru (as Prime Minister) and Chintaman Dwarkanath Deshmukh (as Finance Minister and President of the Indian Statistical Institute), and the band of talented statisticians who gathered around him and who themselves made significant contributions to statistics. Among those who came under the influence of the Professor include such outstanding statisticians as the late S. S. Bose, J. M. Sengupta, R. C. Bose, the late S. N. Roy, K. R. Nair, R. R. Bahadur, G. Kallianpur and D. B. Lahiri.

A significant role in the development of the Institute was played by the late Shri Pitambar Pant. Pant was Secretary to Jawaharlal Nehru during the Independence Movement in India. He was deputed by Nehru to the Institute to learn statistics in 1946. He was associated with the Professor since then and constantly helped him in all negotiations with the government, which often turned out to be delicate and difficult. Although Pant was never an employee of the Institute, he took considerable interest in it and gave much of his valuable time to the Institute's work. He held the honorary positions of Joint Secretary and Vice-President of the Institute, and for a long time directed the activities of the Delhi Branch of the Institute.

Thirties and Forties—The present author was associated with the Professor for over thirty years, having joined the Institute in 1941 as a student in what was called the Training Section of the Institute. As there were no regular courses in statistics anywhere else in India at that time, the Institute attracted talented students from all parts of India. In addition, there were trainees deputed by government organizations and universities to take courses in statistics or to learn specific statistical techniques applicable to their problems. There used to be about ten students in the class and the duration of the training course was one academic year. The teaching was somewhat disorganized. Mahalanobis himself was too busy with the affairs of the Institute and his duties as Professor of Physics, and he never gave any regular lectures. There were others at the Institute (R. C. Bose, S. N. Roy, K. R. Nair, K. Kishen and A. Bhattacharya) doing research work and making fundamental contributions in specific areas of statistics, such as design of experiments and multivariate analysis. They discussed the students' problems in the classes but did not attempt to give any systematic treatment of statistics, as they themselves were engaged in learning the subject. There were two staff members, S. Sengupta and Chameli Bose who had degrees in Statistics from the London University, who

tried to cover the general area of statistics as developed by Karl Pearson. After completing training at the Institute and obtaining the Master's degree in statistics from Calcutta University, the present author was appointed to the staff in 1943.

Working in the Institute was an exciting experience. One had the freedom to pursue one's own ideas, to participate in the projects of the Institute, to accept administrative responsibilities or to devote time to research.

The Institute was engaged in conducting several sample surveys, consumer expenditure, public opinion, forecasts of acreage and yield of crops. Under the leadership of Mahalanobis, much pioneering work was done in the design of sample surveys, organization of field work and tabulation of results, for which the Institute received wide recognition. Some of the mathematicians in the Institute concentrated more on theoretical problems based on the research work initiated by Sir Ronald Fisher and Professor Mahalanobis in field experimentation, anthropometry and meteorology. Significant contributions were made in the areas of multivariate analysis, design of experiments, combinatorial mathematics and estimation by the workers of the Institute.

There was also the training section already referred to, which started in July 1938 where courses were given in theoretical and applied statistics spread over an academic year leading to a 'Certificate of Training.' A scheme of external professional examinations was started in 1938 for the award of the Computer's Certificate and Statistician's Diploma of the Institute on the same lines as the external examinations leading to the Fellowship of the Institute of Actuaries in England.

Fifties and Sixties—There were fresh developments in the fifties and sixties which were to give the Institute its special character. In 1950, the Institute undertook the responsibility of technical direction and tabulation of the National Sample Survey data, which meant considerable expansion in the staff of the Institute at both technical and non-technical levels. A new division of Statistical Quality Control was started in 1953 to provide consultation service to industry and this meant the establishment of a number of branches of the Institute in different parts of India. The Institute's planning units in Calcutta and Delhi were expanded in 1954 to undertake studies in economic planning on behalf of the Government of India. A few years earlier, two research units, one for Sociology and another for Demography, started functioning. The fifties also saw the establishment of an Electronics Division and Workshop for the development of computers.

The Institute was declared as an Institute of national importance and empowered to award degrees by an Act of Parliament in 1959. The Institute immediately introduced undergraduate and post-graduate programmes leading to B.Stat., M.Stat., and Ph.D. degrees. The Institute continued to attract brilliant students. Some of them, D. Basu, G. P. Patil, T. N. Srinivasan, V. S. Varadharajan, K. R. Parthasarathy, R. Ranga Rao, S. R. Vardhan, and D. K. Roychoudhury have achieved international recognition.

Earlier a research unit in Biometry was started with a few workers, which considerably expanded when Prof. and Mrs. J.B.S. Haldane joined the staff of the Institute and branched off into a number of independent units, anthropometry, botany, agriculture, human genetics, embryology and biochemistry. About the same time,

Psychometry (under the leadership of Dr. Edwin Harper) and Linguistic research units were established. At the suggestion of Professor Haldane, Dr. Pamela Robinson of the London University was invited to start a geological research unit. With the introduction of the B. Stat. course, the departments of physics and chemistry were opened. Two research units, one for immuno-chemistry and another for leaf protein work, were established recently.

Thus the I.S.I. as it exists today, is a many-faceted organization. It functions as a university in its educational programmes and degree-awarding activity, as a corporation in undertaking large-scale projects, as a firm of consultants for industry to improve productivity and as a meeting place of scientists, economists and literary figures from all parts of the world.

Visitors are often intrigued to find such diverse and unrelated activities in the I.S.I., some of which may appear to be far removed from statistics, and also a Geological Museum with a rich collection of palaeontological material including dinosaur fossils. But to Prof. Mahalanobis, such diversification was a necessity. Though Statistics has its origin in gambling and demography, it grew in importance as a principal tool in scientific investigations, and statistical methodology has today been applied to the study of many problems.

Mahalanobis Distance

The first opportunity to use statistical methods came to Mahalanobis when N. Annadale (then Director of Zoological Survey of India) asked him, during a chance meeting at the Nagpur session of the Indian Science Congress in 1920, to analyse the anthropometric measurements taken on Anglo-Indians (of mixed British and Indian parentage) in Calcutta. This study led to Mahalanobis's first scientific paper published in 1922 in the records of the Indian Museum under the title 'Anthropological observations on the Anglo-Indians of Calcutta.' This was a remarkable contribution. Among other things, it established Mahalanobis's skill in applying statistical methods for extracting information from given data and drawing inferences. This study was followed by a number of other investigations, based on anthropometric measurements, which led to the formulation of the statistic, known in statistical literature as '*Mahalanobis Distance*' and widely used in problems of taxonomical classification.

Mahalanobis was not satisfied with just providing a tool for cluster analysis based on a specified set of measurements. His logical mind had led him to raise fundamental issues connected with the application of the D^2 statistic. He argued that inferences drawn on affinities between populations might depend on particular measurements chosen for study, in which case the conclusion would not have the desired practical significance. The configuration may change, and even the order relations between distances may be disturbed, if one set of measurements is replaced by another. Mahalanobis was, therefore, led to lay down an important axiom for the validity of cluster analysis called dimensional convergence of D^2 .

Mahalanobis also pleaded for the standardization of anthropometric measurements so that data obtained by different investigators are comparable. In a paper

published in 1928 in '*Biometrika*,' he examined the anthropometric data available from different sources and showed how a comparative study was not possible because of differences in the definitions of measurements in different investigations. He also emphasized the need for scrutiny of field records and devised systematic methods for detecting recording errors and making adjustments.

Mahalanobis's early work on statistical analysis of anthropometric data and the theoretical problems it raised opened up a rich field of research in multivariate analysis to which several of his colleagues at the Institute have made valuable contributions.

In addition to his duties as Professor of Physics at the Presidency College, Mahalanobis also worked as a Meteorologist in Calcutta, in charge of the Eastern Region, from 1922 to 1926. During this period, he carried out a number of statistical studies on meteorological data, some of which were published in 1937.

Early Examples of Operations Research

In 1922, a disastrous flood occurred in North Bengal. An Expert Committee of engineers appointed by the Government was about to recommend the construction of expensive retarding basins to hold up the flood waters, when the question was referred to Mahalanobis for examination. A statistical study of rainfall and floods extending over a period of 50 years showed that the proposed retarding basins would be of no value in controlling floods in North Bengal. The real need was improvement of rapid drainage and not holding up the flood water. Specific remedies were recommended, many of which were implemented and proved effective.

A similar question of flood control in Orissa was referred to Mahalanobis, after a severe flood in the river '*Brahmini*' in 1926. An Expert Committee of engineers were of the opinion that the bed of the '*Brahmini*' had risen, and they recommended increasing the height of river embankments by several feet. The statistical study covering a period of about sixty years showed that no change had occurred in the river bed, and the construction of dams for holding up of excessive flood water in the upper reaches of the river would provide an effective control. Mahalanobis also pointed out that dams could be used for the generation of electric power needed for the economic development of the region. He also gave the first calculations for a multipurpose (flood control, irrigation and power) scheme for the '*Mahanadi System*' in Orissa, which formed the basis of the Hirakud Hydroelectric Project inaugurated about thirty years later in 1957.

In retrospect, one finds that Mahalanobis's early work on river floods is in the nature of operations research (O.R.) introduced as a separate discipline after the Second World War. Another example of such an approach is the study he made, in a note submitted to the Government of Bengal in 1937, on the Hooghly-Howrah Flushing and Irrigation Scheme. He had estimated the expected increase in the yield of paddy by the introduction of an irrigation scheme by which high floods in the Damodar river were intended to be used to supplement the rainfall. This report

was of some help in developing in later years the Damodar Valley Multipurpose Hydroelectric Project.

Education Tests

Mahalanobis developed an interest in the construction and performance of educational tests in his early days of statistical research. Group tests in the medium of the Bengali language were constructed and used in the Institute. Studies were also made of the correlation between intelligence or aptitude tests and success in school-leaving certificate and other examinations, and of standardization of tests.

The Institute has now a separate division for the development of educational and vocational tests. It offers a regular service to educational institutions for the admission of students and to industrial establishment for the recruitment of skilled personnel.

Errors in Field Experimentation

In 1925, Mahalanobis had occasion to study the probable errors of results of agricultural experiments in which six varieties of paddy had been sown in a systematic manner in ten replicated blocks. In this study, the variation in soil heterogeneity was sought to be eliminated by fitting non-linear graduating curves (a method which was used independently by J. Neyman several years later). Mahalanobis was not aware of experiments introduced a few years earlier by R.A. Fisher, and suggested that each strip or plot should be divided into a number of sub-plots with a view to securing replicated observations for the computation of error. This paper placed him in touch with R. A. Fisher, and Mahalanobis immediately began to study seriously Fisherian methods of field experimentation. During a visit to England in 1926, he met Fisher, and a close personal relationship was established which was strengthened by Fisher's frequent visits to the Indian Statistical Institute. The two had common views on the foundations and methodological aspects of statistics, and also on the role of statistics as a new technology. Fisher's death in 1962 removed a very close friend of Mahalanobis.

Large-Scale Sample Surveys

Large-scale sample survey techniques as practised today owe much to the pioneering work of Mahalanobis in the forties and fifties. He recognised the need for sample surveys in collecting information, especially in the developing countries, where official statistical systems are poor and 'data are treated as an integral part of the administrative system regulated by the principle of authority.' A sample survey, properly conducted, would provide a wealth of data, useful for planning and policy purposes, 'expeditiously, economically and with a reasonable degree of accuracy,' and at the same time 'ensuring objectivity of data.'

The methodology of large-scale sample surveys was developed during 1937-44 in connection with the numerous surveys planned and executed by the Institute. Some

were on consumer expenditure, tea-drinking habits, public opinion and public preference, acreage under a crop, incidence of plant diseases' rupee census and so on. The basic results on large-scale sample surveys were published in 1944 in the '*Philosophical Transactions of the Royal Society*' and also presented at a Meeting of the Royal Statistical Society, London.

Mahalanobis made three notable contributions to sample survey techniques, namely, pilot surveys, concept of optimum survey design, and interpenetrating network of samples.

The concept of pilot surveys as developed by Mahalanobis was the forerunner of sequential analysis developed ten years later by the late Abraham Wald. A pilot survey serves many purposes. It provides basic information on operational costs and the variability of characters, which are two important factors in designing an optimum survey. It gives an opportunity to test the suitability of certain schedules or questionnaires to be used in the survey. A pilot survey can also be used to construct a suitable 'frame' for sampling of units.

From the beginning, Mahalanobis was very clear about the principles involved in drawing up a good sample design. A method proposed in this connection by Mahalanobis sparked off a controversy in India, some supporting small-sized cuts and others advocating larger ones. The controversy still exists although it has been repeatedly demonstrated that small circular cuts are more economical, operationally more convenient, and free from bias when the procedure is properly standardized.

Besides the variance function, the optimization problem involves the knowledge of cost function for field operations as well as for statistical analysis.

One of the greatest achievements of Mahalanobis is the establishment of the National Sample Survey (N.S.S.) in 1950. It is a continuing exercise employing a large number of field investigators spread over the entire country for collection of information on socio-economic and demographic aspects of the population, periodically, on a sampling basis. During the last twenty-two years the N.S.S. has provided valuable information needed by the government in the formulation of the five-year economic plans and for taking policy decisions from time to time. The N.S.S. is recognized as an integral part of the official statistical system in India for the collection of data. But it took years to convince the government and the users of the data that sample surveys, when properly organized, can provide reasonably accurate estimates of a wide variety of economic variables expeditiously and at low cost, and periodically at desired points of time. The task proved to be extremely difficult especially because there was no parallel anywhere in the world in the use of a continuing sample survey covering an entire country for collecting official statistics.

Mahalanobis was concerned more with the practical aspects of sample surveys, rather than with mathematical research on survey sampling. As Chairman of the United Nations Sub-Commission on Sampling (1947-51), he advocated the use of sample survey methods in less developed countries for the collection of socio-economic and demographic data and laid down specifications for conducting large-scale sample surveys.

Fractile Graphical Analysis

It is said that a scientist's best work is done when he is young; as he grows older he can only elaborate on his earlier ideas. But Mahalanobis was an exception. Throughout his long years of research he had been continually providing new ideas and new tools for statistical analysis. During the last ten years of his life he developed a semi-non-parametric method for comparison of two samples, which he called fractile graphical analysis. This method was first developed for comparison of socio-economic conditions of a group of people at different points of time or of two groups of people at two different places. Applications have been found in other fields such as demography, psychology, biometry, etc.

CONTRIBUTIONS TO PERSPECTIVE PLANNING

Mahalanobis's acquaintance with economics was neither systematic nor complete. The economics he learnt was connected with the problems he had to solve, and these came intermingled with problems in other fields. In his studies on rainfall and floods in the Damodar valley and Hirakud project areas conducted in 1931, he mentioned the need for regional planning and made some suggestions. He had even given a plan for development of roads.

Mahalanobis initiated a number of family budget surveys in rural and urban areas during the forties. He also undertook a number of studies on consumer preferences. He even tried his hand on rupees census, estimating the life of a rupee coin. A survey of the after-effects of the great Bengal famine in 1943 made him acutely aware of the poverty of the country.

In 1949, Mahalanobis became the Chairman of the Indian National Income Committee, when he began to think about the macro-economic problems of India. There were gaps in information of computing national income. To fill this, he established the National Sample Survey (N.S.S.) in 1950, and also organized a statistical unit devoted to the study of national income. When Mahalanobis was called upon to help in the planning work of the Government, he took up the study of planning models. He realized that the models suitable for advanced countries might not be applicable for underdeveloped countries. Setting himself the twin objectives of doubling the national income and reducing unemployment considerably over a period of twenty years, he produced what are now known as Mahalanobis two- and four-sector models for economic development.

Mahalanobis's association with the Planning Commission and his involvement in the formulation of the Second Five Year Plan brought him into contact with problems of wider national and international importance. He wrote extensively on subjects like (i) priority of basic industries, (ii) role of scientific research, technical man-power and education in economic development, (iii) industrialization of poorer countries and world peace and (iv) labour problems, unemployment and demographic problems.

Mahalanobis considered scientific advance as a prerequisite of sustained economic development. Economic progress entails technological change that could be

brought about only by engineers and technologists. Sustained technological research could only prosper in an atmosphere in which science in general is flourishing.

In his writings on scientific research, technical manpower education, etc., one could discover beginnings of a theory of economic growth. While the role of innovations in economic development has been stressed by Schumpeter and others, Mahalanobis emphasized the connection between scientific advance and technological innovations and the role of decision making at the appropriate time.

Mahalanobis discussed labour problems in India with particular reference to unemployment. The notion of unemployment had to be different in India in view of the existence of a large body of self-employed persons. *'As they do not have jobs, they cannot lose jobs, and cannot, therefore, be unemployed in the sense of industrial countries'*. On the other hand, manpower is grossly under-utilized in the country, and this applies to both self-employed and workers and employers. In addition, Mahalanobis thought that the conditions of living had not improved materially for the working class in comparison with the Prewar Period and labour productivity probably remained stagnant over the time. The solution according to him has to be simultaneous improvement in productivity, efficiency and remuneration.

In this context, Mahalanobis's idea of Labour Reserve Service (L.R.S.) run by government assumes considerable importance. When a particular worker is thrown out of a job, the enterprise should make a payment of L.R.S. Under the circumstances, a person will be thrown out only when the anticipated benefit is more than the payment to be made. All such workers will be maintained by the L.R.S., financed by the government and payments received from enterprises. The workers in L.R.S. will receive training and be engaged in productive work, the average wage in L.R.S. being slightly lower than the industrial wage. With industrial expansion, the enterprise will provide employment to members of L.R.S. at nominal wage rates, the L.R.S. thus serving as a buffer against unemployment. Since enterprises will be able to fire a worker on grounds of economy and efficiency, it will be possible for them to attain high productivity. On the other hand, the workers will find a regime free from any apprehension of unemployment.

HONOURS AND AWARDS

Mahalanobis received numerous awards from academic societies all over the world for his contributions to statistics and economic planning. He was elected Fellow of the Royal Society of London (1945), Fellow of the Econometric Society, U.S.A. (1951), of the Pakistan Statistical Association (1952), Honorary Fellow of the Royal Statistical Society, U.K. (1954), of King's College, Cambridge (1959), Honorary President of the International Statistical Institute (1957), Foreign Member of the U.S.S.R. Academy of Sciences (1958), Fellow of the American Statistical Association (1961), and Fellow Member of the World Academy of Arts and Science (1963). He received the *'Weldon Medal'* from Oxford University (1944), *'Gold Medal of the Czechoslovak Academy of Sciences (1963)'* on his seventieth birthday, the *'Sir Deviprasad Sarvadhikari Gold Medal (1957)'*, *'Durgaprasad*

Khaitan Gold Medal (1961)' and the '*Srinivasa Ramanujan Gold Medal* (1968)', all for contributions to science.

He was a Founder Fellow of the Indian National Science Academy (1935), and its President (1957-58). He was President of the Indian Science Congress in 1950. He received Honorary Doctorates from Calcutta (1956), Delhi (1964), Stockholm and Sofia Universities.

He received one of the highest civilian awards, '*Padmavibhushan*', from the Government of India in 1968 for his contributions to science and services to the country.

LIFE WITH A MISSION

The seventy-nine years of the Professor's life were full of activity. His contributions were massive, on the academic side, as the builder of the Indian Statistical Institute, Founder and Editor of *Sankhya*, organizer of the Indian Statistical Systems, pioneer in the applications of statistical techniques to practical problems, promoter of the statistical quality control movement for improvement of industrial products, and as the architect of the Indian Second Five Year Plan.

Statistical science was a virgin field and practically unknown in India before the twenties. Developing statistics was like exploring a new territory. It needed a pioneer like Mahalanobis, with his indomitable courage and tenacity to fight all opposition, clear all obstacles and throw open wide pastures of new knowledge for the advancement of science and society.

With the passing away of Professor Mahalanobis, India has lost an outstanding personality, the like of whom is born perhaps once in several generations.

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AMIYA CHANDRA BANERJI

(1891-1968)

Foundation Fellow 1935

AMIYA CHANDRA BANERJI, the eldest son of Gyanendra Chandra Banerji, a Zamindar of Maheshtala in 24-Parganas was born on September 23, 1891 in Bhagalpur, the home of his maternal grandfather, where his father was practicing law. The young Amiya spent his childhood with the family of his maternal grandfather at Bhagalpur.

EARLY LIFE AND EDUCATION

Before formal school education, the child Amiya received the fundamentals of cultural education at home according to Brahmo beliefs. A high sense of duty, tolerance towards fellowmen, comprehension of human values marked this early training. His formal school education was at the Bhagalpur Zila School where he came under the influence of inspiring and devoted teachers. In his own words "I vividly remember the Head Master of my High School who inspired me to become a teacher." Thus it would appear that his resolve to become a teacher was made quite early in his life. After a brilliant school education, Banerji came to the Presidency College, Calcutta. Here he came in contact with many pioneer scientists including Acharya Jagdish Chandra Bose and Acharya Prafulla Chandra Ray. His mathematics teacher, Shyam Das Mukherji had a very original mind and encouraged challenging thoughts from his students. Banerji passed the M. Sc. examination from Calcutta University in Mathematics in 1913 in the first division. At this stage, the question of the future of young Banerji came up. He was offered a job in Government. At the same time, he came to know that the Government of Bihar had offered a scholarship to an M. A. or M. Sc. in Mathematics for further studies in England. Young Banerji had no hesitation in making the choice. He applied for the scholarship and was selected. On 5th September 1915 he left for Britain.

HIGHER EDUCATION IN U.K.

A. C. Banerji was at Clare College, Cambridge, from 1915 to 1919. He was a Foundation Scholar at the College, where he obtained a first class in Part I of the Mathematical Tripos, and became a Wrangler on passing the Part II in first class and secured the *Owst Prize* awarded to the best candidate in Mathematical



A. C. Banerji

Tripes. Soon after, he joined the Cavendish Laboratory where he came in close contact with such distinguished Professors as Eddington, Hardy, Larmour, Wilson and Chapman who had a profound influence on his life and his making. One of his students writes, "*Professor Banerji's insistence on observance of rigour in mathematical proof was almost proverbial. He tolerated no lapses, not even the slightest departures. Even at the under-graduate level, Professor Banerji's teaching had an air of freshness about it. It was not the approach of Loney and Edwards—standard text book writers of the time—but the more modern analytical approach of Hardy, Ramsay and Besant that made his mathematics lectures interesting and prompted a desire for further knowledge among students*".

HIS POPULARITY

At Clare College, he not only proved to be a brilliant student but also distinguished himself in several other spheres of college life. He was very popular among his fellow students and was 'Daddy Banerji' to many of them, an acknowledgment of his genuine interest in their well-being. He was twice elected President of the Clare College Debating Society. His contemporaries admired him for the courage with which he defended his convictions. In the words of Dr. A. H. McDonald, Fellow and former Senior Tutor of Clare College, "*he was one of the most distinguished old Clare men.*"

PROFESSIONAL CAREER AND CONTRIBUTIONS TO NEW KNOWLEDGE

On his return to India he was offered an appointment at Muir Central College, which later became the nucleus of the Allahabad University. He taught applied mathematics there. His methods of teaching as well as his mastery of the subject soon earned for him the admiration from his pupils. He showed that Mathematics was more than problem solving. He demonstrated that there was elegance in mathematical methods. He was fond of rigour. His love and affection for his students who showed intelligent interest and devotion to work knew no bounds of formality. They had full and free access to his personal notes and library. He did not believe in living in an ivory tower. He was very sociable by nature and lived a life of unsophisticated simplicity. In the evenings his home was a regular rendezvous of students, teachers and people from other walks of life. The discussions were lively, informal and informative. To many they were a liberal education. The content of his lectures, his devotion and approach to the subject and his personal contact with the students prompted in them a keen desire for further knowledge and for advanced studies in Mathematics.

During his stewardship, the Mathematics Department of Allahabad University rose to great eminence. It was acknowledged as a pre-eminent Centre of Mathematical Studies throughout the country and attracted students from all parts of India. One finds today his former students occupying high academic positions and who remember him with gratitude and fondness.

He developed a good school of researches in applied mathematics in general

and theoretical astrophysics in particular. In theoretical astrophysics his association with Prof. M. N. Saha was of great importance. The two together made the school unique in the country which earned global recognition for it. Prof. Banerji's originality was recognised internationally from his very first work on 'the cepheid theory of the origin of the solar system'. It figures in almost all important books on astronomy. The idea was different from the then prevalent one of Professor Jeans of Cambridge. Almost of equal significance are his contributions, 'The physical theory of oscillating universe' and 'The method of promotion of the arms of a spiral nebula'. Each represents his deep and original thinking and boldness of expression, qualities inherent in him. Besides these, he and his students made important contributions in several fields like Astrophysics, Hydrodynamics, Wave Mechanics, Nuclear Physics, Theory of Relativity and Galactic Dynamics.

HONOURS AND DISTINCTIONS

In recognition of his eminence in his field, the Government of India wished to establish a Central Observatory and deputed him to America and England to visit laboratories and observatories there. Professor Banerji received many honours at home and abroad. He was associated with several scientific and academic organisations. He was:—

1. Fellow of the Royal Astronomical Society.
2. Foundation Fellow of the National Institute of Sciences (Indian National Science Academy) and its Founder Secretary.
3. Foundation Fellow of National Academy of Sciences of India, its Founder Secretary and elected Vice-President.
4. President of :
 - (a) Debating Society of Clare College, Cambridge;
 - (b) U. P. Secondary Education Conference;
 - (c) Mathematics Section of Indian Science Congress (1940);
 - (d) Banaras Mathematical Society (1941-44);
 - (e) The Indian Astronomical Society; and
 - (f) The Indian Planetary Society.
5. President, Calcutta Mathematical Society (1945-47, 1962).
6. Member, International Astronomical Union.
7. Member, Calendar Reform Committee.
8. Member, Standing Advisory Board in Astronomy.
9. President elect of Indian Science Congress, 1969.
10. Vice-Chairman of Birla Planetarium Advisory Committee.

Professor Banerji possessed many human qualities. He was honest, frank and had simple manners. He was a man of his word and a trusted friend. His students and colleagues held him in very high esteem. As a result he was elected Vice-Chancellor of Allahabad University.

As Vice-Chancellor, he proved to be a good administrator and the University made notable progress. In view of his vast experience as teacher and University

administrator he was asked to draw up the Constitution of Vindhya Pradesh University and later, after retirement, he was appointed Adviser to the Jadavpur University during 1956-58.

After 1958, he returned to Allahabad University as Emeritus Professor of Mathematics where he worked and guided research students till the very end. He died suddenly on May 31, 1968. Professor Banerji was an exemplary teacher, a great inspiring researcher, a man of vision, an affectionate 'Daddy' to his pupils, a democratic and able administrator. In tribute to him I cite the hymn of the *Rig-Veda*:

"We invoke your soul, which has journeyed in the path of space. Let it come back and be established in us".

R. S. KUSHWAHA

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T. Vijayaraghavan

TIRUKKANNAPURAM VIJAYARAGHAVAN

(1902-1955)

Foundation Fellow 1935

TIRUKKANNAPURAM VIJAYARAGHAVAN was born on November 30, 1902 in Adoor Agaram, a village in South Arcot district of the State of Tamil Nadu. He died of a heart attack on April 20, 1955 in Madras. His father was a distinguished scholar, both in Sanskrit and in Tamil, who left an abiding impression on the son's personality. From him, Vijayaraghavan derived a passion for intellectual pursuits for the study of literature and philosophy, ethics and religion. Interesting as those studies were, it was mathematics that presented a real challenge to his powers, and revealed the full scope of his genius.

EARLY LIFE AND EDUCATION

He went to various schools, at Tirukkannapuram, Mannargudi, and Kudavasal, and matriculated from the Hindu Theological High School at Madras. He fared well at school, and won a few prizes. He did his Intermediate (1918-20) in Pachaiyappa's College, and his Honours (1920-24) in Presidency College, Madras. He was genuinely interested, even at that stage, in serious mathematics, and had already begun thinking about research problems which could have stumped many of his teachers. To any one like him who was ready to set off on the path of mathematical discovery, much of the college curriculum and most of the teaching could hardly have seemed anything but boring. There was a shining exception, however, in Professor K. Ananda-Rau whose recognition of the young Vijayaraghavan's talent had not only been necessary for his admission to Presidency College, but sufficient to protect him from the grind of rules and regulations. In later years, Vijayaraghavan used to recall with nostalgic pleasure his meetings, as a student, with Ananda-Rau, and the inspiration he had drawn from the teacher.

Even before he finished college, he published a research note (1920) on the set of limit points of the set $\{\phi(n)/n\}$, where $\phi(n)$ the number of integers less than n and prime to n . He showed that every point in the interval $(0, 1)$ is a limit point of the set $\{\phi(n)/n\}$. The problem is simple and the solution not difficult. But the result is interesting; it is neither a routine generalization nor an obvious analogue of a known theorem. This aspect of his work is perhaps the most important.

SIMILARITY TO RAMANUJAN

At about this time (1921—), he began sending some of his manuscripts to Professor G. H. Hardy in England. This must have seemed the obvious thing for him

to do in view of the already well-known Ramanujan story. Hardy's response was not immediate. It was only some time later, after Mr. S. R. Ranganathan who had been a member of the mathematics staff of Presidency College had met Hardy and inquired about the matter, that Hardy had the manuscripts looked into, and wrote to the University of Madras that Vijayaraghavan's mathematical talent deserved recognition, and that he should be enabled to go to England to work with Hardy. The University of Madras accordingly offered him a scholarship to go to New College, Oxford (1925). This story, if not quite so romantic as Ramanujan's, has clearly a touch of similarity, since Vijayaraghavan had at that time no academic degree, and it was not only excusable but quite understandable if several people in Madras came to look upon him as a kind of spiritual successor to Ramanujan. It is not clear whether Vijayaraghavan himself felt that way, but there is no doubt that he was in the grip of the romance of Ramanujan, to the extent of believing that native wit rather than training and knowledge—to use his own words—was the principal requisite for research. Almost everyone would agree with that standpoint, but his singularity lay in the emphasis that he placed on the first at the expense of the second. It may seem somewhat paradoxical, though, in fact, it is revealing, that he placed great emphasis on scholarship, comment, and criticism, as far as (Sanskrit or Tamil) literature was concerned—he was not creative in that field—, whereas in mathematics he paid a little less respect to such things, and reserved his admiration almost exclusively, and of course rightly, for original and creative work. Vijayaraghavan himself used to say, especially in his later years, that he liked people to tell him “what was happening”, and to come up to him with problems, so that he could have a go at them. His note on linearly ordered spaces is an instance in point. It was in the course of a casual conversation, on the work of a student supplicating for the M. Sc. degree, that Vijayaraghavan came across the two questions: Is a connected, linearly ordered topological space, which has the power of the continuum, separable? Is a connected topological space, of which every point is a cut point (i.e., its removal splits up the space into two and only two disjoint connected open sets), linearly ordered? Although his knowledge of set topology, at that time, hardly extended beyond the definitions, he produced the answers (which are in the negative in both cases), after three days or so of trial and error. As he said, this only showed that the problems were not deep, and that he could learn quickly; but it also showed, what Vijayaraghavan might not have been too ready to own, that to ask the ‘right’ questions was itself part of the game, and quite an interesting part.

AT OXFORD

Vijayaraghavan spent three years at Oxford (1925-28) working with Hardy. During that time he published several good papers, on divergent series, continued fractions and diophantine approximation; and, of course, got his D. Phil. In his brilliant preface to Hardy's *Divergent Series* Littlewood has remarked: “...in the early years of the century the subject, while in no way mystical or unrigorous, was regarded as sensational, and about the present title, now colourless, there hung

an aroma of paradox and audacity." Although it is difficult to decide whether Littlewood's "early years of the century" included the twenties, it seems quite proper to say that the subject of divergent series did offer, at the time Vijayaraghavan was working on it, problems which were neither colourless nor dull, and his work did show the analytical finesse of a good and gifted mathematician.

CONTRIBUTIONS TO MATHEMATICS

He worked on Tauberian theorems, of the pre-Wienerian variety, and his first contribution (1926) consisted in a simplified proof of R. Schmidt's theorem on Abel means. The well-known converse of Abel's theorem, due to Tauber (1897), states that if Σa_n is Abel summable to a finite sum, and $na_n = O(1)$, then Σa_n converges. Littlewood (1910) replaced the condition $na_n = O(1)$ in Tauber's theorem by the much more general one $na_n = O(1)$; and Hardy and Littlewood (1914) replaced Littlewood's two-sided condition by the one-sided condition $na_n > -c$. R. Schmidt (1925) proved the result with the far more general condition

$$\liminf (s_m - s_n) \geq 0, \quad s_m = \sum_{r=0}^m a_r, \quad m > n, \quad m \rightarrow \infty, \quad n \rightarrow \infty, \quad \frac{m}{n} \rightarrow 1.$$

Vijayaraghavan gave a simplified proof of Schmidt's theorem, without using the theory of the Stieltjes moment problem as Schmidt had done. Vijayaraghavan also extended (1928) his argument from Abel's method to Borel's method, and gave a simplified proof of another theorem of R. Schmidt: If Σa_n is summable by Borel's

method to a finite sum s , and $s_n = \sum_{r=0}^n a_r$, and $\liminf (s_m - s_n) \geq 0, \quad m > n, \quad m \rightarrow \infty, \quad n \rightarrow \infty, \quad n^{-1/2}(m-n) \rightarrow 0$, then $s_n \rightarrow s$. Here again he dispensed with the use of the

theory of the moment problems of Stieltjes and Hamburger, and applied, instead, an extension of the principle of repeated differentiation originally invented by Littlewood. All this work is interesting, and shows very intricate and deep analysis, but the subject was raised to an altogether different level by Norbert Wiener (1930) with the aid of the theory of Fourier transforms. However, in order to obtain the classical results as corollaries, Wiener did have to adopt methods which were strongly influenced by the work of his predecessors.

In the same line of research, he obtained (1927) converse theorems on summability (of series with real terms) when the sums are infinite, instead of being finite as usual. He showed that there is a difference in behaviour between $(C, 1)$ means and Abel means on the one hand, and a difference in the operation of unilateral and bilateral Tauberian conditions on the other. He proved the following results:

1. If Σa_n is summable (A) to sum s , $|s| = \infty$, and $|a_n| < k/n$, then $\Sigma a_n = s$.
2. If Σa_n is summable (A) to sum s , $s = -\infty$, and $a_n > -k(n \log \log n)^{-1}$, then $\Sigma a_n = s$.
3. There is no sequence of negative numbers b_n such that Σb_n is divergent, for which the hypotheses that Σa_n is summable (A) to sum s , $s = \infty$, and, $a_n \geq b_n$ imply that $\Sigma a_n = \infty$.

4. If Σa_n is summable $(C, 1)$ to sum s , $s = \infty$ and $a_n > -k n^{-1}$ then $\Sigma a_n = s$.
5. If Σa_n is summable $(C, 1)$ to sum s , $s = -\infty$, and $a_n > -k(n \log \log n)^{-1}$, then $\Sigma a_n = s$.

From (4) and (5), we see that in the case of $(C, 1)$ summability the Tauberian condition required when $s = +\infty$ is less stringent than when $s = -\infty$. In the case of (A) summability, on the other hand, we observe from (2) and (3) that if $s = +\infty$, no strengthening of the Tauberian condition will yield a positive, non-trivial result, whereas if $s = -\infty$, the result is analogous to the $(C, 1)$ case. We also observe from (1) that these niceties are absent in the case of a two-sided Tauberian condition.

In connexion with Vijayaraghavan's Tauberian theorems should also be mentioned his Mercerian theorem. Mercer proved (1907) that if

$$A_n \equiv s_n + at_n \equiv s_n + a \frac{s_1 + \dots + s_n}{n} \rightarrow s, \text{ as } n \rightarrow \infty,$$

where $a > 1$, then $s_n \rightarrow s$. Between 1912 and 1923 there appeared a variety of proofs of this theorem, including one by Hardy and another by Knopp. Vijayaraghavan generalized it (1928) by proving that if $s_n + q_n t_n \rightarrow 0$, with $\liminf q_n > -1$, then $t_n \rightarrow 0$. If the additional condition that q_n is bounded is imposed, then $s_n \rightarrow 0$, thereby yielding Mercer's theorem as a corollary.

Besides Tauberian theorems, Vijayaraghavan published (1927) a paper on continued fractions, a subject in which he began to evince interest since his Honours days. In proving the classical result of Lagrange that every quadratic surd corresponds to a periodic, simple, continued fraction, it is shown that if a quadratic surd has the representation $(P + \sqrt{R})/Q$, where $|P|, |Q|, R$ are (the least) positive integers for which it is true that $Q \mid (R - P^2)$, then the number of elements in the periodic part of the corresponding simple continued fraction is less than $2R$. Vijayaraghavan improved this estimate by showing, in an elementary way, that the $2R$ can be replaced by $O(R^{\frac{1}{2}+\epsilon})$, $\epsilon > 0$. More precisely, he showed, by using some results of I. Schur, that if $N(R) \equiv N(P, Q, R)$ denotes the number of elements in the smallest period of the continued fraction corresponding to $(P + \sqrt{R})/Q$, then $N(R) = O(R^{\frac{1}{2}} \log R)$, and that for an infinity of values of R , $N(R) > R^{\frac{1}{2}-\epsilon}$, $\epsilon > 0$, and for an infinity of R , $N(R) = O(\log R)$, the O 's being uniform with respect to P and Q . Associated with this result is another by him on the solvability of the Pellian equation $Rx^2 = y^2 + 1$. It is well known that this equation is, or is not, solvable in integers according as the continued fraction for $\sqrt{R}$ has, or has not, a period with an odd number of elements. Vijayaraghavan considered the more general surd $(P + \sqrt{R})/Q$, and showed that it has, or has not, a period with an odd number of elements, according as the Pellian equation is, or is not, solvable for R .

Vijayaraghavan's paper (1927) on Diophantine approximation arose out of the famous memoir on the subject by Hardy and Littlewood [*Acta Math.*, **37** (1914) 155-190]. Let (x) denote the fractional part of x , and $\phi \equiv \phi(\lambda, \theta, \alpha)$ denote the least positive integer n , for which the approximation $|(n\theta) - \alpha| < 1/\lambda$ holds. Confirming a conjecture of Hardy and Littlewood, Vijayaraghavan showed that for particular choices of θ and α one could make ϕ arbitrarily large, for a sequence of values of

λ tending to infinity. More precisely, given $\Omega \equiv \Omega(\theta, \alpha)$ and $\psi = \psi(\lambda, \alpha)$, which are two arbitrary functions, finite for all values of their arguments, the first independent of λ , and the second of θ , one can find an α for which $0 \leq \alpha < 1$, and an irrational number θ , such that $\phi > \Omega \psi$, for an infinity of values of λ . Since Kronecker's fundamental theorem on diophantine approximation suggests the plausibility of a similar result with any finite number of θ 's, Vijayaraghavan considered the case of two θ 's, and proved something different, namely: If $\phi \equiv \phi(\lambda, \theta_1, \theta_2, \alpha_1, \alpha_2)$ denotes the least positive integer n for which it is simultaneously true that

$$|(n\theta_1) - \alpha_1| < \frac{1}{\lambda}, |(n\theta_2) - \alpha_2| < \frac{1}{\lambda},$$

then given $\Omega \equiv \Omega(\theta_1, \theta_2, \alpha_1, \alpha_2)$, $\psi \equiv \psi(\lambda, \alpha_1, \alpha_2)$, which are two arbitrary functions, one can find two linearly independent irrationals θ_1 and θ_2 , and two numbers α_1 and α_2 , such that for *all* large λ , $\phi > \Omega \psi$. It is to be noted that whereas in the first case, the result on the increase of ϕ holds for a sequence of values of λ , in the second case the result holds for *all* large λ . This difference is interesting because it results in different answers, in the two cases, to the question of how small, instead of how large, one can make ϕ . It had been observed by Hardy and Littlewood, in the first case, that to any θ and α there corresponds a sequence of values of λ tending to infinity, for which $\phi < \frac{1}{2}\lambda$. Vijayaraghavan's result shows that in the case of two θ 's there is no such theorem.

After his return home from Oxford (1928), Vijayaraghavan took up an appointment in Annamalai University for a year; he moved to Aligarh, as a Lecturer, in 1930. There he came in contact with Professor André Weil for whom he conceived a great admiration. In 1931, he went to Dacca University as a Reader, and remained there till 1946. The first important piece of work after his return from Oxford relates to a conjecture of Borel.

Borel proved in 1899 that if $y=f(x)$ is a real continuous function of a real variable x , which satisfies an algebraic differential equation of the first order, say

$$F(x, y, y') = 0, \quad (*)$$

for $x > x_0$ where y' is the first derivative of f , and F is a polynomial in x, y, y' , then

$$y = o(e^{ex}) \equiv o(e_2(x)).$$

Borel conjectured that similar results would hold for differential equations of higher order; in particular, for equations of the second order, he believed that he could prove that

$$y = o(e_3(x)).$$

Lindelöf [*Bull., Soc. Math.*, **17** (1899), 205] gave a more precise form of Borel's theorem namely, that if equation (*) is of degree m in x , there exists a constant c , such that

$$y > e^{cx^{m+1}},$$

for $x > x_0$. Hardy took up this problem in 1912 [*Proc. London math. Soc.*, **10** (1912), 451-468], and remarked that, in the case of the second-order equation, Borel's proof is "not complete, but its general lines are indicated". He added: "There is no

doubt of the truth of the corresponding general theorem, though, so far as I am aware, no strict proof has ever been given". In his paper, Hardy did not attack the general problem, but obtained refinements of Borel's theorem in the case of first-order equations. Any one who looked into Hardy's paper would have felt the urge to prove the plausible general theorem. Vijayaraghavan showed however, that the analogue of Borel's theorem, for equations of higher order, was false; and that, even in the case of first order equations, it would be false if the restriction that the solution should be real was not imposed. His proof (1932) is ingenious, simple, and beautiful, and shows Vijayaraghavan at his best. It consists in considering the real part of a Weierstrassian elliptic function with suitably chosen periods, and deservedly attracted the notice of distinguished mathematicians like G. D. Birkhoff. It was only a few years later (1936) that, on Birkhoff's initiative, he was invited to the United States as a Visiting Lecturer of the American Mathematical Society. Vijayaraghavan used to cherish the memories of that visit, and long before American universities earned "recognition" in Indian bureaucratic circles, he used to impress on his younger colleagues some of the great things for which American universities stood. Vijayaraghavan returned in 1937 to his disproof of Borel's conjecture, and in collaboration with his colleague at Dacca, Professor N. M. Basu, and with the distinguished physicist Professor S. N. Bose, constructed an extremely simple example; If $\phi(x)$ is an arbitrary, real increasing function, tending to $+\infty$ with x , and

$$f(x) = \frac{1}{2 - \cos x - \cos \alpha x},$$

for a suitably chosen irrational α , depending on ϕ , then

$$|f(x)| > \phi(x)$$

for a sequence of values of x tending to infinity, although f is a real, continuous solution of an algebraic differential equation of the second order. Actually x is chosen in the following way. Let $\{d_n\}$ be a sequence of positive integers, such that

$$d_r > 4\pi \phi(2\pi q_{r-1}), \quad r = 2, 3, 4, \dots,$$

where $q_r = d_1 d_2 \dots d_r$, $r = 1, 2, 3, \dots$ then take $\alpha = \sum_{r=1}^{\infty} 1/q_r$.

While the simplicity of this example should not moderate one's praise for Vijayaraghavan's ingenuity in the first place, it does remind us that the value of "negative" results is a changeable thing, and that in a total assessment of one's work, as distinct from one's powers, negative results occupy a relatively minor place.

His next major interest was the study of the fractional parts of powers of real numbers. Let θ be a real number. Consider θ^n , $n=1, 2, \dots$. Let $G(\theta)$ denote the set of limit points of the fractional parts of θ^n . It was proved by Hardy and Littlewood [*Acta Math.*, 37 (1914), 181] in their study of some problems of Diophantine approximation that the set E of real numbers $\theta > 1$ for which $G(\theta)$ is not the entire unit interval is of Lebesgue measure zero. The problem of determining the arith-

metrical nature of the 'exceptional' set E naturally arose. Hardy himself took this up in 1919 (*J. Indian math. Soc.*, **11** (1919), 162-166], and quickly realized that while the general problem was "one of great difficulty", the answer was "almost immediate" in the case in which θ was an algebraic integer. He proved the following theorem: Let (x) denote the fractional part of x . Let a be a real, algebraic number, greater than 1, which is the root of an irreducible equation

$$k_0 a^m + k_1 a^{m-1} + \dots + k_m = 0,$$

where $k_0, k_1, \dots, k_m$ are integers. Then in order that numbers $\alpha > 0$ should exist which satisfy the condition

$$(\alpha a^n) \rightarrow 0, \text{ as } n \rightarrow \infty,$$

it is necessary and sufficient that $k_0 = 1$, so that a is an algebraic integer, and that the moduli of all the roots of the above equation, other than a itself, should be less than 1.

In his series of four papers on the subject, Vijayaraghavan proved, among other things, the following theorem which generalizes Hardy's, in as much as it considers the case in which $G(\theta)$ consists of any finite number of points, instead of only one (namely the point zero) as in Hardy's case: If $\{u_n\}$ is a sequence of real numbers

$$u_n = d_1 \xi_1^n + d_2 \xi_2^n + \dots + d_l \xi_l^n, n = 1, 2, 3, \dots$$

where $d_1, d_2, \dots, d_l \neq 0$, $\xi_1, \xi_2, \dots, \xi_l$ are distinct algebraic numbers with $|\xi_i| > 1$, and if the limit points of fractional parts of u_n are finite in number, then $\xi_1, \xi_2, \dots, \xi_l$ are algebraic integers; moreover, if η is a conjugate of one or more of the numbers $\xi_1, \dots, \xi_l$, but is not one of them, then $|\eta| < 1$. This theorem led him to ask whether the hypothesis that $G(\theta)$ is a finite set implies, in itself, that θ is algebraic. Although he could not prove that, he showed that the set of θ 's for which $G(\theta)$ is a finite set is enumerable, and the set of θ 's for which $G(\theta)$ is not the entire unit interval (which had been shown to be of measure zero by Hardy and Littlewood) has the power of the continuum.

Vijayaraghavan was led to this general result by a series of simple but interesting results. Throughout these it turns out that the class S of algebraic integers θ whose conjugates, other than θ , have an absolute value less than 1, plays a special part. This class, which has been sometimes referred to as the class of Pisot-Vijayaraghavan numbers* (since M. Pisot had independently encountered it) originated explicitly in Hardy's paper (1917, loc. cit) on the same subject.

In attempting a study of $G(\theta)$, for real $\theta > 1$, Vijayaraghavan began with the simplest case in which θ is rational. In this case he proved that $G(\theta)$ has an infinity of points (Weil gave an alternative proof of this result). On the other hand, if $\theta \in S$, he showed that $G(\theta)$ has only a finite number of points. This, however, does not mean that for all algebraic integers θ , $G(\theta)$ is a finite set, for he showed that there exist algebraic integers θ for which $G(\theta)$ consists of the entire interval

*Prof. C.L. Siegel in his introduction to the *Selected Mathematical papers of Axel Thue* (Oslo 1977), shows that in fact the discovery of these numbers goes back to Axel Thue (1912) and that the nomenclature "Pisot-Vijayaraghavan numbers" is somewhat unjust to Thue.

(0, 1). It is still not known if every real algebraic $\xi \geq 1$ which is not in S is such a θ . It follows, as a particular case of his theorem quoted earlier, that for all real algebraic numbers $\xi \geq 1$ other than those that belong to S , $G(\xi)$ has an infinity of points.

The part played by the set S in the above considerations led Vijayaraghavan and others to study it more closely. Vijayaraghavan himself showed that S contains algebraic integers of all degrees, and gave some of the limit points of S which are also members of the set, and conjectured that it was improbable that S could be everywhere dense in some interval, or be dense in itself. Later Salem showed [*Duke Math. J.*, **11** (1944), 103-108] that the set S is closed and since it is enumerable, it follows that it is nowhere dense, nor dense in itself, confirming Vijayaraghavan's conjecture. Siegel determined [*Duke Math. J.*, **11** (1944), 597-602] the first two members of the set S to be θ_1 and θ_2 , where θ_1 is the positive zero of $x^3 - x - 1$ and θ_2 the positive zero of $x^4 - x^3 - 1$. Siegel further showed that any other point of the set is greater than $\sqrt{2}$. The set is connected with the study of sets of uniqueness and of multiplicity for trigonometric series, through Salem's conjecture that the perfect set P , of Cantor's type, with the constant ratio of dissection $(\xi, 1 - 2\xi, \xi)$, $0 < \xi < \frac{1}{2}$, is a set of uniqueness for trigonometric series if and only if $1/\xi$ belongs to S , Salem has proved [*Trans. American math. Soc.*, **54** (1943), 218-228; **56** (1944), 32-49; **63** (1948), 595-598] that if $1/\xi \in S$, then P is a set of multiplicity, though it is not yet known whether P is a set of uniqueness if $1/\xi \in S$ [Salem and Zygmund subsequently answered this question in the affirmative in *Comptes Rendus, Paris*, **240** (1955), 2281-2283.]

Although Vijayaraghavan wrote several other papers, none of which is trivial, it seems safe to say that his proof of the Tauberian theorem on Borel summability, his disproof of Borel's conjecture, his note on Diophantine approximation, and his work on the limit points of fractional parts of powers of a real number, constitute his best achievement. He was found, on at least one occasion, to express an opinion akin to that.

HIS LAST DAYS

In 1946, he resigned his position at Dacca, and was appointed to a Professorship in Andhra University. That was the first chance he got, as he used to remark, of heading a department. He had plans of some sort for building up a school at Waltair, but they never came to fruition, and he left that university in 1949 to be Director of the privately endowed Ramanujan Institute of Mathematics, intended to be located at Karaikudi, but functioning, for the time being, at Madras. It was his ambition to make that Institute an important research centre, and he sought the support of the Government of India to that end. The response, one imagines, was neither immediate nor adequate, and he passed away before his dream could be realized.

AN INTELLECTUAL

Reviewing his work, one cannot fail to be impressed by its uniformly high

quality. His analysis was in the genuine Hardy tradition. His whole approach to mathematics was strongly influenced by Hardy whom he admired not only as a mathematician but as a truly great individual. He liked to solve problems, and classified them according to their order of importance. He was a mathematician of taste, and of considerable strength; he never liked to publish anything trivial; he strove for originality. He was precise. On the other hand, all his main problems, almost entirely, arose out of the work of Hardy and Littlewood. He did no pioneering; he was interested in theorems, not theories. He viewed mathematics, more or less, as an infinite, discrete set of interesting problems. The structures of mathematics, their inter-relationship and architecture were somewhat unreal to him. His mathematical powers were undoubtedly greater than his achievements. And no one who knew him intimately,—as a working mathematician, as a delightful conversationalist, as a genial host, or as an affectionate father,—could fail to say: here was an intellectual of whom his country could be proud.

Vijayaraghavan loved lecturing, and was a lucid, effective, and sometimes brilliant lecturer, especially on mathematical topics which were of immediate interest to him. His dialectical skill and sophistication were used to great advantage. He loved to give alternative proofs, counter-examples, plausible arguments, and generalizations; and it gladdened his heart to know that at least some members of the audience appreciated his effort and his skill. It was a pet saying of his that one could not claim that one knew a theorem, unless one could give not less than three different proofs of it, of which at least one proof was one's own. There was a mock-serious occasion when this saying landed him in considerable embarrassment. He was desirous of attracting good students, and believed, as he well might, that he did his very best to encourage talent. It has to be admitted, however, that his efforts were not rewarded with success, and he felt somewhat frustrated and disappointed. It is a surprise that such a truly accomplished lecturer attracted so few 'regular' pupils. At least a part of the answer is to be found in the intellectual milieu in which his lot was cast. Another point is that his intellect functioned according to Toynbee's principle (regarding civilizations) of challenge and response. He needed intellectual companionship of a kind provided by a Hardy or a Weil or a Pillai. This was vouchsafed to him only for brief intervals, and although his reputation rests on solid foundations, it could, and perhaps would, have been greater under more propitious circumstances.

HONOURS

Vijayaraghavan was for many years a member of the Indian Mathematical Society, of the London Mathematical Society and of the American Mathematical Society. From 1947 to 1955 he functioned as a Member of the Council of the Indian Mathematical Society, first as Secretary, then as President, and later as Librarian. He was ever in favour of establishing a high standard for the Society's publications, and gave his unreserved support for many proposals aimed at bringing it about. His premature death was mourned not only by his aged mother, his

wife and children, but by the entire mathematical community in India and by his many distinguished friends abroad.

K. CHANDRASEKHARAN

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GANESH PRASAD

(1876-1935)

Foundation Fellow 1935

GANESH PRASAD was born on November 15, 1876, in the district town of Ballia in U.P. His parents were Ramgopal Singh and Juthan Debi. After finishing his school course in Ballia, Prasad moved to Allahabad. He was admitted in Muir Central College and there he read Mathematics with Prof. Homersham Cox — a Wrangler of the Cambridge University. Prasad was much impressed and influenced by his teacher. In fact, Prasad's choice of a mathematical career later was primarily due to Cox. Prasad graduated with high honours from the Allahabad University and then took his M.A. from both Allahabad and Calcutta Universities. Subsequently, he obtained the D.Sc. degree from the Allahabad University. He worked for short periods as Lecturer in the Allahabad Kayastha Pathshala and then at the Muir Central College. In 1899, he proceeded to England with a Government of India stipend and joined the Christ Church College, Cambridge. There he read Mathematics with men like Hobson, Forsyth and Whittaker and took his B.A. of the Cambridge University. At Cambridge, he prepared a thesis on the conduction of heat, but later left Cambridge to continue his research in Gottingen. There he was a pupil of Prof. F. Klein and came in touch with mathematicians like Hilbert and Sommerfeld.

PROFESSIONAL CAREER

After completing five years of study in Europe, he came back to India in 1904 and took up the position of Professor at Queen's college, Banaras. Later, he became Professor of Mathematics and Principal of the Banaras Hindu University. About this time, attempts were being made by the great educationist Sir Asutosh Mookerjee who was then the Vice-Chancellor of the Calcutta University, to establish Post-Graduate Departments in Arts and Sciences for higher study and research in the University. In 1912, the University founded the Hardinge Professorship of Higher Mathematics, named after the then Governor-General and Chancellor, Lord Hardinge, out of the grant made by the Government of India, to run the newly created Department of Pure Mathematics. In 1913, Prof. W.H. Young, F. R. S. was appointed the first Hardinge Professor. In 1914, the University founded four Rashbehari Ghosh Professorships in Applied Mathematics, Physics, Chemistry and Botany out of the magnificent donations made by Sir Rashbehari Ghosh. In the same year, Ganesh Prasad was invited to be the first Rashbehari Ghosh Professor of Applied Mathematics, a post which he held with credit till 1918. Later, after the retirement in 1923 of Prof. Cullis who was the



James Read

successor of Prof. Young, Ganesh Prasad was invited by Sir Asutosh to occupy the Hardinge Chair which post he held with great distinction till his death in 1935.

SOCIAL VIRTUES, IDEAS AND OUTLOOK

Prof. Ganesh Prasad was short in stature but strongly built. He was courteous and cordial to all those who came in contact with him. His relations with his pupils were parental; he was always ready to help them either in their mathematical work or in obtaining employment. He regarded his intimate friends and colleagues as members of a family and took interest in their welfare. He was always active and agile and enthused others to work hard. His love for Mathematics was unbounded.

After the death in 1924 of Sir Asutosh Mookerjee, who was the Founder President of the Calcutta Mathematical Society, Prof. Prasad became the President of the Society and remained as such till his death. In 1930, he brought out the Commemoration Volume of the Bulletin of the Society on the occasion of the 20th anniversary of the foundation of the Society in 1928. This volume contains about 20 papers contributed by eminent mathematicians from all parts of the world. Prof. Prasad was also the Life-President of the Banaras Mathematical Society. In 1932, he delivered the Presidential Address to the Mathematics and Physics Section of the Indian Science Congress Association. He was a good speaker and his addresses were heard with rapt attention. As Hardinge Professor his reputation travelled far in the country. He attracted a number of talented young men from different parts of the country whom he inspired to do research work specially in the theory of functions of a real variable. Among his students special mention may be made of the four who distinguished themselves in later years by their valuable contributions. They are Mr. Hariprasanna Banerjee of the Department of Pure Mathematics, Calcutta University, the late Prof. B. N. Prasad of the Allahabad University, the late Prof. A. N. Singh of the Lucknow University and Prof. Brij Mohan Mehrotra of the Banaras Hindu University. Mention must also be made of one whom Prof. G. Prasad held in high esteem and to whom he often turned for advice and collaboration, the late Dr. Bibhutibhusan Datta of the Department of Applied Mathematics, Calcutta University, who distinguished himself as historian of Hindu Mathematics of ancient and medieval times.

GLIMPSES OF HIS PERSONAL LIFE

Prasad married early and had one child, a daughter, Krishna Kumar Debi, born in 1896. Soon after the daughter was born, her mother died leaving Prasad a widower throughout the rest of his life. Naturally, all his affections centered round this daughter; but alas, fate snatched her away when she was only 16. It was a traumatic experience but Prasad bore it bravely by immersing himself in study and research. His life was unostentatious and simple. Towards the end of his life, he lived practically alone with servants to look after him; but he was always accessible. His residence was a picture of plain living and high thinking with books and journals heaped here and there. He cherished affectionate memories of his

daughter and parents. He endowed a medal and prize in the name of his daughter for research in History of Mathematics. He also dedicated his book "*A Treatise of Spherical Harmonics*" in two parts, to the memory of his daughter and his book "*Some Great Mathematicians of the 19th Century*", in two volumes to the memories of his parents. The profession of teaching and living a scholar's life were highly congenial to him; and though he took some part in the political life of his province, being elected to the Legislative Council of U.P., he gave public life a go-by at the earliest opportunity and entered his study as the fit habitation of a scholar. A scholar's life he led up to the last moment when he collapsed while addressing an academic meeting at Agra on the 10th March, 1935.

CONTRIBUTIONS TO MATHEMATICS

Prof. Prasad was mainly an analyst. Arithmetisation was his favourite method. He was truly Weierstrass's successor although he began as Klein's pupil. His life was full of adventures in the domain of Pure Mathematics. He was a prolific writer. Besides 50 original papers and addresses published in various mathematical journals, both Indian and foreign, he wrote about 10 memoirs and treatises on higher mathematics. Some of his writings were translated into German.

(A) Original Papers

His first paper on potentials of ellipsoids of variable densities which appeared in 1901 is an important one. In this paper, he gave a method of expansion of certain functions in a series of certain types. The remarkable feature of this method is that it gives a simple and elegant expansion of any algebraic integral function in series of spherical harmonics and that it can be applied in any function space in any number of dimensions. The author also shows how to obtain the definite integral expression for the potential of an ellipsoid of variable density when the potential of a homogeneous ellipsoid is known.

His next paper on the 'Constitution of matter and the analytical theory of heat' which appeared in 1903 is also very important. Klein has pointed out that it is in this paper that a satisfactory solution of the physical problem was given. It is known that starting from Fourier down to Franz Neuman, Poincaré and Lamé, every mathematician dealing with the problem of heat conduction has taken into consideration solutions of the differential equations concerned in a smoothed out uniformly convergent form. Prasad showed that if one starts with integral expansion method, one can get a logically valid result in a range, no matter whether the range is dense everywhere or not. Therefore the real discontinuous distribution of matter may also be taken into consideration and the difficulties experienced by earlier mathematicians can be removed by the application of this method.

The third important paper on 'Expansion of an arbitrary function' in a series of spherical harmonics appeared in 1911. Its German translation came out in the next year. The result given in this paper has been quoted by Hobson in his book on '*Spherical Harmonics*.' The process of expansion is such that it may be made possible to expand an arbitrary function into particular infinite

asymptotic series of a given type. That type may be chosen as that of spherical harmonics.

Then it is necessary to mention here that a couple of important papers on the Failure of Lebesgue's criterion were published in 1928. The smoothing out process recommended by Lebesgue was improved by Frejer. Prasad showed how the behaviour of a function with discontinuity of the second kind can be controlled. Then in 1930, he published a paper on the Function θ in the mean-value theorem of the Differential Calculus. In this paper, the author investigated as fully as possible the nature of the number $\theta(h)$ for a fixed value of x and gives a lot of useful informations. The logical acumen of the author stands out pre-eminently in this paper.

(B) *Addresses to Learned Societies*

The address on Mathematical research in the last 20 years given in 1920 to the Banaras Mathematical Society gives an interesting outlook on the progress of Mathematics in a certain period in certain directions. It has been translated into German. It deals specially with Integral equations, Foundations of mathematical physics, Generalisation of the notion of convergent series and Development of the principle of relativity. We may then refer to his Readership lectures on Partial differential equations in mathematical physics delivered in 1924 to the Patna University. In these lectures, Prasad considers partial differential equations arising from (1) Vibrating phenomena, (2) Analytical theory in the conduction of heat, (3) Gravitational, electrostatic and magnetostatic causes, and (4) Hydrodynamical and electrodynamical sources. We may also refer to his Address, published in 1933, to the Calcutta Mathematical Society in memory of Prof. Hobson, the distinguished Sadlerian Professor of Cambridge, dealing with his life and mathematical works. This address is an interesting document in many respects. In his early career, Prasad was a student of Hobson and was influenced by him. For, in later years, Prasad's works often touched common grounds with Hobson's, e.g., works on Bessel and Legendre functions, spherical harmonics and Fourier series. However, according to Prasad, the greatest achievement of Hobson was the bringing out in 1907 of his treatise "*The Theory of Functions of a Real Variable and the Theory of Fourier Series*". The printed address ends with a facsimile of a letter of Hobson to Prasad.

(C) *Treatises and Memoirs*

Notice may be taken of Prasad's Introduction to the theory of elliptic functions and higher transcendentals (six lectures) published in 1928. This memoir gives a general account of the old and modern theories of elliptic functions, applications and an expert's review of some special functions. We may then take notice of his treatise of '*Spherical Harmonics and the Functions of Bessel and Lamé*', in two parts, published in 1930, 1932. This is a very useful text book for the beginners in the subject. In the first part, parameters are considered positive integers and the arguments real whereas in the second part parameters and arguments are considered unrestricted.

Another outstanding work of Prof. Ganesh Prasad is "*Some Great Mathematicians of the 19th Century*", in two volumes. The first volume came out in 1933 and the second in 1934. Alas, a contemplated third volume could not see the light of the day. Volume one deals with the lives and works of the six front rank mathematicians: Gauss, Chauchy, Abel, Jacobi, Weierstrass and Riemann while volume two deals with the lives and works of ten others: Cayley, Hermite, Krönecker, Brioschi, Cremona, Darboux, George Cantor, Mittag-Leffler, Klein and Poincaré. The volumes contain portraits of the mathematicians and make very interesting reading. Much information and incidents of historical interest are given in the books. The aim of writing these volumes has been, as the author says, "*to place before the minds of the readers the highest types of mathematicians so that not only every young and accomplished mathematical scholar but also the budding mathematical genius of the future may strive to attain to the highest ideal of mathematical scholarship and research*".

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GIRIJA PRASANNA MAJUMDAR

(1894-1959)

Elected F.N.I. 1943

GIRIJA PRASANNA MAJUMDAR was born on 18th February, 1894 at Gopalnagar, Pabna District (now in Bangla Desh). The Majumdar family of Gopalnagar village was very well known in those days. His father was Krishendra Narayan Majumdar, a landlord of Gopalnagar and his mother was Kumud Kamini Devi. Girija Prasanna was the fourth of six sons. He was later adopted by his uncle Kalicharan Majumdar.

EARLY LIFE AND EDUCATION

Girija Prasanna received his earlier education in the village High School at Gopalnagar. He was later admitted in the Zilla School at Pabna Town from where he passed the Entrance Examination in 1909. With a view to prosecuting higher studies, Majumdar proceeded to Calcutta where he joined the Bangabasi College. He passed the I.Sc. examination in 1911 and took the B.Sc. degree from the same College in 1913. In College, he came in close contact with the well-known educationist and Professor of Botany, the late Girish Chandra Bose who created in young Majumdar much interest in Botany. Soon after he passed the B.Sc. examination, he was appointed Demonstrator in the Botany Department, Presidency College, Calcutta. During this period, Girija Prasanna prepared himself as a private student for the M.Sc. examination in Botany and obtained his Master's degree in 1915. Young Girija Prasanna also studied the humanities and passed the B. A. examination of the Calcutta University with distinction in 1916. He studied Law too and passed the B. L. examination in 1917.

AT THE PRESIDENCY COLLEGE, CALCUTTA

Soon after his passing the M. Sc. examination in Botany, he was appointed Lecturer in Botany and later Professor of Botany at the Presidency College, Calcutta. He was associated with the Post-Graduate Department of the Calcutta University since 1928. At the Presidency College, he started research on various aspects of the history of Botany and also carried out studies on Plant Anatomy and published several papers in different journals of India. He left for England in September, 1938 to carry out research under Professor J. H. Priestley of the University of Leeds. His work on the apical organisation of plant organs, particularly in *Heracleum sphondylium* brought him the Ph.D. degree of the University of Leeds in 1940. At Leeds in the Department of Botany, he had with him two



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more Indians, Dr. P. Misra of Ravenshaw College, Cuttack and the writer. During his stay in England he worked also on the X-ray diffraction pattern of collenchyma cells in collaboration with Professor Preston.

RESEARCH WORK

On his return from England, Dr. Majumdar continued to carry out research work on plant anatomy and published several scientific papers. He tried to develop a band of research workers on plant anatomy. He had discussed with the present writer, who also worked as a Professor at the Presidency College till 1945, the possibilities of developing an Institute of Plant Anatomy in India; Professor Majumdar worked hard on this Project, but this did not materialise for want of support.

Professor Majumdar made extensive researches on the genesis and development of Botany and Agriculture in Ancient India and his contribution to the subject was unique in the country. After collecting data from many Sanskrit texts he compiled an excellent and authoritative account about botanical science in Ancient India for which the '*Griffiths Prize*' of the Calcutta University was awarded to him in 1925. It was later published as '*Botany in Ancient India*'. He edited and translated the '*Upavana Vinoda*', an ancient text on arbori-horticulture in India and also edited the '*Krishi Parasara*', a Sanskrit text on agriculture, which was published by the Asiatic Society. He also published a book on "*Some Aspects of Indian Civilization in Plant Perspective*". This book is regarded as an authoritative publication on the subject by scholars throughout the world. In 1933, in collaboration with the late Professor B. M. Barua, Head of the Department of Pali, Calcutta University, he published in the '*Calcutta Review*' a paper entitled "Flying machine in Ancient India". The existence and development of 'aeroplanes' in Ancient India was proved and clearly narrated from different sources. Dr. Verdoorn of the '*Chronica Botanica*', Massachusetts, U. S. A. invited him to write a volume on the History of Botany in India but he could not undertake the work due to ill-health.

Dr. Majumdar was a keen research worker and worked till the end of his life. He was the foremost worker on developmental plant anatomy in this country. In his Presidential Address to the Indian Science Congress, "Some aspects of anatomy in modern research" he elaborated many aspects of plant anatomy in great detail. This article is still considered as a masterpiece and referred to by workers on the subject throughout the world.

In addition to his research publications in English, Dr. Majumdar published many interesting popular articles on botanical subjects in Bengali in different Bengali journals.

HONOURS

Professor Majumdar was associated with various scientific bodies of the country. He was Fellow of the National Institute of Sciences of India (at present the Indian National Science Academy), the Indian Academy of Sciences and the Indian

Botanical Society. He presided over the Section of Botany of the Indian Science Congress in 1945 and over the Section of Technical Sciences, All-India Oriental Conference in 1947. He was President of the Indian Botanical Society in 1949, Vice-President in 1950 and Secretary, Treasurer and Editor-in-Chief in 1942-43, 1944 and 1948-49 respectively. He was also President of the Botanical Society of Bengal from 1947 to 1948. He was for sometime Vice-President of the National Institute of Sciences of India, Biological Secretary of the Asiatic Society and the Joint Editor of Publications, National Institute of Sciences of India. For a short period he officiated as the Secretary of the Asiatic Society.

MARRIAGE AND CHILDREN

Dr. Majumdar was first married in 1912. His wife was Charuprova Devi, the daughter of late Jogesh Chandra Bhowmik, Deputy Superintendent of Police, Rangpur. She died after a few years without leaving any issue. After the death of his first wife he married Sudha Devi, daughter of the late Girish Chandra Sarma, on November 19, 1919. She bore him two daughters and two sons. His eldest son Gouri Prasanna Majumdar is famous as a writer of lyrics and songs in Bengali.

RETIREMENT AND AFTER

Professor Majumdar retired from the Presidency College in 1949. He was however invited by the Education Department, Government of West Bengal to work as a Professor of Botany in the Government College, Darjeeling, to organise the Department of Botany for teaching honours course. In 1951, he was appointed Professor of Botany and Head of the Department of Biology in the University of Dacca, then East Pakistan. While in Pakistan, he acted as the Chairman of the Commission of Courses of the Karachi University. He also presided over the Section of Biology, Zoology, Botany and Entomology at the Annual Session of the Pakistan Association for Advancement of Science in 1955.

As a Professor, Dr. Majumdar was very successful. He inspired his students with new ideas and was held by them in high esteem. Many of them now occupy high positions in the Universities and in Government Departments.

MAJUMDAR AS A TEACHER AND AS A MAN

As a man, Professor Majumdar was unassuming and had a charming personality. He was intensely nationalistic and was actively associated with several national organisations. Except during the two years he was in England, he never wore anything except hand-spun and handwoven cloth. He was a generous man and used to help many poor students. He was fond of acquiring old books and had a good collection of several hand-written manuscripts and many ancient books.

From the beginning of the year 1959, Professor Majumdar was in indifferent health. In spite of it, his interest in research continued unabated and he carried on work on developmental anatomy with the help of a research assistant under the

scheme of aid to retired scientists sponsored by the Council of Scientific and Industrial Research. He had planned to write a review on the Stipules of plants but his end came suddenly and the work was left unfinished. He died of heart failure at 9 a. m. on the 21st of November, 1959. He is remembered well by his students, colleagues, friends, and admirers and all who had come in contact with him.

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Robert A. Heinlein

SUBODH MITRA

(1896-1961)

Elected F.N.I. 1944

SUBODH MITRA was born on 1st November, 1896 in 'Singiaharigara', a village in Dist. Jessore (now in Bangla Desh) in a middle class family of four brothers. He was educated in the local School at 'Narail' and passed his Matriculation Examination in 1914. He also studied in a local College for his Interscience examination after which he went to Calcutta and was admitted to the Calcutta Medical College. He took his M.B. degree in 1922. Later, he proceeded to Germany for advanced training and took his M.D. degree from Berlin University in 1924. He then moved to Edinburgh and passed the F.R.C.S. examination in 1925. On returning to India, he joined as Assistant Superintendent and Resident Surgeon at Carmichael Medical College (now R. G. Kar Medical College). As opportunities for surgical work were not adequate, he left the Institution and took up appointment as Assistant Surgeon at Chittaranjan Seva Sadan Hospital where he worked throughout his life. He was largely responsible for bringing this Institution into a virile active centre for post-graduate Medical Education, Hospital training and Treatment and Research activities. His training in Germany and in Great Britain equipped him for specialization not only in Obstetrics and Gynaecology but also in Radiology.

PROFESSIONAL CAREER AND RESEARCH ACHIEVEMENTS

From the very beginning in his professional career, Dr. Subodh Mitra showed unmistakable aptitude for clean and careful surgery and operative skill. He was an acknowledged leader, specially in the field of Obstetrics & Gynaecology, which brought him to the forefront amongst the practising doctors in this area of work. His fame and reputation were soon established and he was made Director-Professor of Obstetrics & Gynaecology at the R. G. Kar Medical College, Calcutta. He was simultaneously Principal of Chittaranjan Seva Sadan College of Obstetrics & Gynaecology & Child Health. His important contribution was the starting of a special hospital for cancer patients and in this he succeeded in eliciting public support. He himself donated much equipment that was urgently needed for the hospital. His fame as one of India's leading cancer surgeons was soon recognised abroad and he was invited several times to attend Medical Congress and Conferences outside India. He was a delegate to Innsbrück Science Congress (Germany) in 1924; International Radiological Congress in Paris in 1931; Bicentenary Congress of Obstetrics & Gynaecology (Dublin) in 1947; British Congress of Obstetrics and Gynaecology (London) in 1949; International Congress of Obstetrics,

(New York) in 1950; German Congress of Obstetrics (Munich) in 1952; International Cancer Congress (Brazil) in 1954; International Congress of Obstetrics (Geneva) in 1954. In the last mentioned Congress and also in the International Congress of Obstetrics (New York) he was the Section President.

He designed a new technique of operation for Cancer of the Cervix (Extended Radical Vaginal Hysterectomy and Extraperitoneal Lymphodenectomy). This was officially announced in British, American and German Gynaecological Congresses and demonstrated in Vienna in 1952. It is now known all over the world as "*MITRA OPERATION*" for cancer of the cervix.

CONTRIBUTIONS TO MEDICAL TEACHING AND RESEARCH

Dr. Mitra made special scientific contributions to Cancer Surgery of the uterus, Toxemia and Anaemia of pregnancy and fundamental research in general cancer problems. He was the author of more than 100 scientific papers in different English and German Journals. He was commissioned by the Indian Medical Council to inspect Medical Section of the Indian Science Congress. He was Dean of the Faculty of Medicine and Member of the Syndicate and Academic Council of the Calcutta University. He was appointed Vice-Chancellor of the Calcutta University in 1960.

Dr. Mitra received several National and International honours. He was awarded *Honoris Causa* membership of the Society of Gynaecology and Obstetrics of Italy as a mark of his scientific contributions in the fields of Obstetrics and Gynaecology. While attending the 2nd International Obstetrics and Gynaecological Congress in Vienna in 1961 where he acted as Co-Chairman in September, 1961, he died due to coronary heart disease.

PERSONAL REMINISCENCES

Dr. Subodh Mitra married Susama Bhowse of the well-known Bhowse family and has one daughter, Dr. Jayasree Roy Chowdhury, whom he initiated into areas of cancer research in which he was interested but could not carry out during his extremely busy life. The big cancer hospital and research centre in Calcutta is a lasting monument to Mitra's dynamism and dedication to the cause of suffering humanity. Intensely human, he will long be remembered as a brilliant surgeon, a devoted scientist and a generous person.

ACKNOWLEDGEMENT

The present writer is grateful to Dr. Subodh Mitra's Daughter, Jayasree Roy Chowdhury for details about Dr. Subodh Mitra's life and career.

B. MUKERJI

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SAMARENDRA NATH ROY

(1906-1964)

Elected F.N.I. 1944

PROFESSOR S. N. ROY, the eminent Indian statistician who emigrated to the United States of America in 1950, died, while on a holiday-cum-lecture tour in Canada, on 23rd July, 1964.

Roy was born in a distinguished family hailing from the district of Khulna in the former province of Bengal. His father, Mr. Kali Nath Roy, a renowned journalist of the pre-independence era, played an important role in the Indian political movement of those days. Roy had his early education in his native district school and completed his degree courses in the University of Calcutta in 1931 with a master's degree in applied mathematics. He had a uniformly brilliant academic record. He was continuing his advanced study and research in Relativity in the Department of Applied Mathematics, Calcutta University, under the guidance of Prof. N. R. Sen, when he came in contact with Prof. P. C. Mahalanobis, who was conducting at the time some statistical studies in the Indian Statistical Institute founded by him in 1931. Prof. Mahalanobis, in his quest for talent, quickly picked up Roy and thus started him on his statistical career. This contact between Roy and Mahalanobis shaped not merely the future career of Roy but also the development of statistical researches in India.

ROY'S PROMOTIONAL ROLE IN STATISTICAL RESEARCHES IN INDIA

The early history of statistical researches in India is best described by tracing the growth and development of the Indian Statistical Institute, the premier statistical organisation in India. Prof. Mahalanobis started the Institute with his own meagre resources, but it would have been impossible for him, without the devoted services of a group of research scholars and other workers, to develop the Institute to the internationally pre-eminent position it came to occupy. To this group belong such scholars as S.S. Bose, H.C. Sinha, R.C. Bose, S.N. Roy and others. Initially, the burden fell on S.S. Bose, but on his untimely death in 1938 at the age of thirty-two, the responsibility largely devolved on S.N. Roy.

The Institute made great strides in 1937 by organising large-scale sample surveys of jute acreage in Bengal. For a full appreciation of the significance of this step it is necessary to mention that sample surveys have been recognised as the major component of statistical work in India and even today the surveys employ the largest number of statisticians. These surveys require, besides theoretical knowledge wide practical experience. Roy was endowed with a unique combination of



S. N. Roy

theoretical ideas and a practical bent of mind and was amply suited for this work and, along with R. C. Bose and others, assisted Prof. Mahalonobis immeasurably in formulating his various plans for sample surveys. During this period, Roy sacrificed his own interests in theoretical research and made himself available for writing reports, drafting papers and other work in connection with the sample surveys.

As statistical research developed in the country, the Institute had to create facilities for training in statistics. It initially began as personal instruction to the officers sent on deputation by Government. But gradually regular courses of training were framed. Roy turned out to be a very popular teacher both in his mastery of the subject and lucidity of exposition. In fact he was assigned the task of interpreting Fisher's theory of estimation and Neyman-Pearson's theory of hypothesis-testing to both students and teachers in the training course.

In 1941, a full-fledged post-graduate course in statistics was started in the Calcutta University with Prof. P. C. Mahalanobis as Head of the Department of Statistics. R. C. Bose and S. N. Roy joined as lecturers and bore the main burden of teaching work. After the departure of R. C. Bose for the United States, S. N. Roy continued as the Head of the Department till 1950 when he also left for the United States. During his short stay in the Department he succeeded in setting high standards of teaching and research.

Roy was one of the founders of the Calcutta Statistical Association and took a keen interest in its activities till his death.

In the midst of all the activities cited above, he found time to carry on original researches and made fundamental contributions to mathematical statistics. These contributions will be reviewed in some detail below. Here it can only be observed that Roy initiated researches in several directions. His students and co-workers have drawn much inspiration from him and owe not a little to his advice and guidance for their own research activities.

ROY'S DEPARTURE FOR THE UNITED STATES

Roy's statistical researches won him recognition at home and abroad. He was elected Fellow of the National Institute of Sciences of India in 1944 and Fellow of the International Statistical Institute in 1951. He presided over the deliberations of the Statistics Section of the Indian Science Congress held in Patna in 1948. On an invitation from the United States, he visited that country in 1949 and delivered lectures at a number of universities as Visiting Professor of Statistics. He could not complete his programme there and returned to reorganise the Statistical Institute as an Institute of National Importance and Roy felt he would have wider scope for his work here. However, Indian conditions being what they were, he soon realised that his hope was unlikely to be fulfilled. He believed that he could create, for Indian students, more opportunities of work abroad than here. So he left for the United States in March 1950, to join the Statistics Department of the University of North Carolina as full-time Professor. He however fulfilled his promise of promoting statistical researches in India from abroad by

affording facilities for a host of Indian students, by his occasional visits and lecture tours in India and in many other ways.

ROY'S HUMAN QUALITIES

Great as an original thinker and statistical worker, Roy was much greater as a man. He had exceptional human qualities. His easy adaptability to changing circumstances, his wide interests, his genial nature and, above all, his feeling of sympathy and consideration for others won him respect, friendship, love and affection. One remembers how he could enliven any company by his sparkling wit and humorous anecdotes. Prof. R. C. Bose of North Carolina University, who was his close associate for over thirty years, writing about him in the *'American Statistician'* (December 1964) remarks: "*S. N. Roy was one of the most self-effacing of men. To his students and to his numerous friends and relatives he gave of his best without any regard for his own conveniences.*" No truer words could be written about him.

ROY'S CONTRIBUTIONS TO STATISTICS

Roy's contributions to mathematical statistics can be conveniently reviewed under the following heads:—

- i) Multivariate analysis
- ii) Testing of hypotheses
- iii) Analysis of categorical data

Multivariate Analysis

Roy started work in this field in 1937 with two preliminary papers (jointly with P. C. Mahalanobis and R. C. Bose), on the rectangular co-ordinates and their uses in the derivation of the sampling distribution of statistics based on normal multivariate samples. Thereafter in 1938 he (jointly with R. C. Bose) derived the distribution of the studentised D^2 -statistic. Though Hotelling's T^2 which is equivalent to D^2 found its use in testing the equality of the mean vectors of two multivariate normal populations with the same dispersion matrix, Roy's work made possible the study of its power properties. In 1941-42, he proposed a set of p -statistics for testing the equality of two dispersion matrices, and a similar set of p -statistics for the multivariate analysis of variance problem. These statistics were derived, following the technique of Fisher, as roots of determinantal equations involving two Wishart matrices. The derivation of the joint distribution of these statistics, the maximum or the minimum of them, formed the subject of a series of papers from 1939 to 1945. Though some of the results were not as general as he intended them to be, they opened a new path in multivariate analysis. Later, he followed a different approach to the problem, viz., that of providing simultaneous confidence bounds for important parametric functions, e.g., characteristic roots of one or two normal dispersion matrices, various combinations

of regression parameters etc., and this is expounded in a number of papers from 1953 to 1963. He extended the scope of multivariate analysis of variance by introducing fixed and random effect models as well as mixed models in a number of his publications from 1959 to 1968. In some of his earlier work on multivariate analysis, he depended heavily on rectangular co-ordinates and higher dimensional geometry. But later he used the more elegant method of matrix algebra, and derived in the process a body of useful results on matrix calculus.

Testing of Hypotheses

Roy studied the various aspects of testing composite hypotheses and was gradually led to propose a heuristic method of test construction—later known as the union-intersection principle. He applied this method to the construction of well-known tests throwing new light on them and also to the derivation of new test criteria in hitherto unsolved problems of univariate and multivariate analyses—this work has already been reviewed in the earlier section.

Analysis of Categorical Data

In the course of his work on multivariate analysis, Roy realised the limited scope of its applicability due to the normality assumption. To forge new tools with a wider field of application, he however did not follow the beaten track of non-parametric analysis, but started right away with frequency data. In fact, he had to devise methods of analysis for multidimensional contingency tables of various types. This required new formulation of the current concepts of correlation, regression, dispersion etc. He also discussed the analysis of mixed types of models in the sense of being partly normal variable type and partly categorical type. For the application of these results one requires a large sample, but that can perhaps be realised more often than the assumption of normality. This work of Roy finds exposition in his book '*Some Aspects of Multivariate Analysis*' and a series of papers with Kartenbaum, with S. K. Mitra (1956) and with Gnanadesikhan (1959).

His last research interest was in the design and analysis of experiments with more than one factor and more than one response. At the time of his death he had under preparation two books and was planning to publish a revised and updated edition of his earlier work '*Some Aspects of Multivariate Analysis*'.

He was a devoted husband and a loving father. He left behind him his wife Mrs. Bani Roy and four children.

Prof. S. N. Roy will be long remembered as an inspiring teacher by many of his students in India and abroad.

P.K. BOSE

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VINAYAK GOVIND PANSE

(1906-1969)

Elected F.N.I. 1944

VINAYAK GOVIND PANSE was born in Maharashtra on January 11, 1906. He had his early education at the Government High School, Nasik. He graduated with a B.Sc. degree in Mathematics, Chemistry and Physics from the Wilson College, Bombay in 1927. In 1940, he went to England to work with Sir Ronald Fisher and extended the study of 'quantitative techniques in plant breeding' by introducing appropriate genetic models which helped to bring out the effects of the number of segregating genes, the magnitude of their action and the modification due to dominance on progress due to selection. This work earned Dr. Panse his Ph.D. from the University of London. World War II interrupted his subsequent studies and he returned to India.

FORMATIVE INFLUENCES

Dr. Panse started his career as Assistant in Agronomy and Chemistry at the Institute of Plant Industry at Indore in 1927. Working here with Dr. J.B. Hutchinson, the noted plant breeder, Panse developed his interest in the use of quantitative techniques in agronomy.

PROFESSIONAL CAREER

On his return from England, where he obtained Ph.D. from London University, he was appointed to the newly created post of Statistician at the Institute of Plant Industry at Indore in 1940.

In 1946, Panse was promoted to the post of Deputy Director, Research, and later was made Director at the Institute. Panse filled this post with such distinction that he was appointed Statistical Adviser to the Indian Council of Agricultural Research in 1951.

At the ICAR, he developed its Statistical Unit into a full-fledged Institute of Agricultural Research Statistics. He was Head of this Institute till 1966. At this Institute appropriate techniques for estimating the area and yield of crops developed, which under his able guidance were soon widely adopted all over the country.

Panse was Secretary of the Indian Society of Agricultural Statistics, which he helped to found in 1947, and Editor of the Society's Journal.

He had just commenced his work as Adviser to the Planning Commission when illness forced him to retire in September 1966.



W. L. Lane

CONTRIBUTIONS TO NEW KNOWLEDGE

Statistical Methods in Agricultural Research:

Plant breeding in the early days was more an art than a science and depended for the most part on the judgment and skill of the breeder. Mass selection was the method in use and consisted in choosing a number of plants which appeared to have superior value, bulking the seed from these, raising from the seed the next generation and continuing selection in this generation. This was obviously inefficient as the selection was subject to a large amount of environmental or non-genetic variability present in the field. Instead of bulking the seed obtained from different selected plants breeders saw the need to sow it in separate progeny rows and to make the selections on the basis of progeny means. The selections thus made were subject to only a fraction of the environmental variation. There was, however, no assurance that the estimates of progeny means were unbiased. The small and variable amount of seed presented further difficulty in arranging replicated trials which could provide sufficiently accurate estimates of the progeny means. The difficulties in conducting randomised replicated tests were particularly large in the early stages of breeding when the material was even more heterozygous. Hutchinson and Panse adapted the randomised block and split plot designs to the plant breeding material and succeeded in the *development of replicated progeny and compact family block designs*.

This, however, was only the beginning of more significant contributions to statistical methods in quantitative genetics. For, apart from efficient field testing, of fundamental importance in plant selection is the recognition that variability in plant population is both genetic as well as environmental. The breeder's success depends upon the initial choice of material containing a high degree of genetic variability and exploiting it to the maximum extent possible. Panse showed that the genetic component of observed variability could be estimated by taking the regression of progeny means on parental value and showed the importance of selecting plants on their deviations from plant means rather than on their own values. He took the study of quantitative techniques a lot further by introducing appropriate genetic models which helped to bring out the effects of the number of segregating genes, the magnitude of their action, the modification due to dominance and the influence of environment.

These results were embodied in a book, '*Statistical Methods in Agricultural Research*', written by Panse and the present author and published by the ICAR in 1954.

Sampling Techniques for Estimating Yield:

The Statistician at the Institute of Plant Industry was also the Statistician to the Indian Central Cotton Committee (ICCC) and in this latter capacity, Dr. Panse was asked in 1941 to make proposals for improving the statistics of cotton production. The Committee was looking for an objective sampling method for estimating the yield per acre.

Panse evolved such a method. It was adopted by the ICCC and it resulted in

improvement of forecasts of Cotton production in the country.

Panse's work had impact on other aspects of Agricultural Statistics. The method of crop-cutting surveys was developed by him for improving the statistics of acreage and yield of other principal crops in the country. Yield surveys based on Panse's method became routine in most States.

Any discussion of the technique of crop estimation would be incomplete without reference to the size and shape of plot in crop cutting surveys. Experiments at the ICAR (1943, 1945, 1947) had shown that plots of small size tend to overestimate yields. This bias resulting from plots of very small size, under Indian conditions, is recognised by all workers but there is no unanimity of opinion concerning the stage at which it becomes negligible. Of this, Dr. Panse wrote in 1948 what is pertinent even today:

"There can be no difference of opinion that with training and supervision the limit at which bias becomes negligible may be reduced. In our view, however, it is not enough to demonstrate that plots of size as small as 50 sq. ft. give unbiased estimates when handled by trained statisticians, nor is it adequate to say that very small plots such as circles of radius 2' should give much less bias than that observed in our investigations. Such results or comments, in our view, have limited value for practical application in India where the employment of a special agency of statisticians for field work in crop sampling work is out of the question and experiments have necessarily to be carried out by the local experimental staff in course of their normal duties. In recommending a method for routine adoption it is therefore of utmost importance to ensure that the method is not susceptible to obvious source of bias in the hands of the agency handling it."

Plot size continues to remain a subject of active research in the country even today.

A number of independent sample checks were subsequently conducted by Panse himself which confirmed that leaving aside questions of concepts and definitions, the acreage statistics derived from the Patwari census were on the whole satisfactory.

The Census of Agriculture:

Panse made significant contributions to the programme and progress of the decennial census of agriculture sponsored by the Food and Agricultural Organisation (FAO). Realizing that lack of basic data constituted a serious handicap in most developing countries in the preparation of their development plans, Panse saw in the census the first step in planning. At the same time he kept in mind the possible impact of the census on the evolution of a sound and permanent system of current agricultural statistics. For two years, 1960-61, he worked as Regional Adviser for Agricultural Census in Asia and the Far East, visited a number of countries in the region to observe the agricultural census in operation and discussed the problem of census-taking with field workers, directors and other technicians engaged in planning, organising and conducting the agricultural census. He incorporated this experience and his own thinking on the subject in a manual he

wrote for the FAO on the problems of agricultural census with special reference to developing countries. In this manual, Panse extended the concept of the agricultural census as an integrated system of surveys. The manual is available in all official languages of the FAO.

It would be rash to conclude that Panse favoured complete enumeration to sampling method for collecting information on items other than land use in the cadastrally surveyed areas.

Panse wrote:

"A view is sometimes expressed that an agricultural census by complete enumeration is a desirable undertaking even if the results are likely to be of imperfect quality and have a limited scope. This view, however, cannot be accepted lightly, for a supposedly complete enumeration census, which is in reality substantially incomplete, would produce results of poor quality and is liable to present a distorted picture of the agriculture structure if carried out under conditions of difficult communications, an ignorant and suspicious peasantry providing biased information and an unmanageable larger number of ill-qualified and ill-trained field staff that must necessarily be employed. Non-sampling errors, such as biased responses, are likely to be appreciable even where the census is substantially complete and it may turn out that the results are consequently less accurate than those of a well-conducted sample census subject to reasonably small sampling errors. It is against this background that a decision whether to carry out a complete enumeration or to project a sample survey will need to be taken. It will also depend upon the level at which the results are required, that is, whether the results will be tabulated for the entire country, for individual provinces, for individual districts or even for their subdivisions. Of course, this decision need not be either a complete enumeration or a sample survey as the only alternative but could well be a combination of both".

Panse extended the application of sampling techniques to a number of other fields. Cost of production studies, estimation of catch of fish, estimation of live-stock and their products, and evaluation of the intensive agricultural district programmes are a few examples.

Economic and Planning Statistics:

Panse's interests have been much wider. His papers published in the '*Indian Journal of Agricultural Economics*' on the index numbers of agricultural production and on trends of crop yields provide two illuminating examples of his interest in developing procedures for evaluating the progress of development plans in the country. They illustrate in a striking manner the contribution which statistical methods can make to the development of evaluation procedures.

Panse's contribution to the development of yardsticks to assess the progress of agriculture have been particularly important. He brought together and analysed the massive data of field experiments on crop response to fertilisers and other inputs in a series of publications entitled '*Index of Experiments*'. These publications, one for each State in the country, were prepared under the guidance of an

Expert Committee of which Panse was Member-Secretary. They contain a wealth of information of great value for planning. This work provided the basic data for developing yardsticks for judging the possibilities of increasing agricultural production in the country and enabled Panse to probe deeply into the technical aspects of India's plan for the development of agriculture. The assessment of the Intensive Agricultural District Programme (IADP) in the country which he carried out for the Sen Committee of the Planning Commission provides an excellent example of this work by Panse.

His article in June 1966 published in '*The Economic Times*' under the heading 'The New Strategy in Agriculture' provides another example. In this, Panse scrutinised the claims of the new strategy in a manner which focused the attention of the public and of the Planning Commission alike. When the new strategy for the development of agriculture was announced in 1964, one was given to understand that one could expect an additional yield of one ton/acre on the average with a fertiliser dose of 100 lbs of Nitrogen and 30 lbs of Phosphate. Panse found no evidence for the claim of the response of 1 ton/acre. With the candour characteristic of him, Panse showed that the available evidence did not justify an assumption of more than half the figure put forward by the Planning Commission. He feared that the claim of 1 ton/acre might lead to over-optimism in the country and an insistence on large doses of fertilizers which were in short supply. He felt that without support of essential scientific data the strategy was unlikely to yield results. This article which Panse wrote in '*The Economic Times*' sometime after he had retired from the ICAR, unfortunately lost for Panse a good deal of popularity in Government circles. But that was always how Panse worked and wrote. He resented doing anything to please anybody, however highly placed.

P. V. SUKHATME

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UMA PRASANNA BASU

(1903-1969)

Elected F.N.I. in 1946

DR. UMA PRASANNA BASU, a distinguished Organic Chemist of India died of stomach cancer on December 1, 1969, one year after he retired as Director, Bengal Immunity Research Institute, Calcutta. Dr. Basu will long be remembered for his contributions to medicinal chemistry and pharmaceutical sciences.

EARLY LIFE AND EDUCATION

Basu came of the well-known 'Basu Mazumdar' family of Lakshmankaty in the district of Borisal (now Bangladesh). He was born in 1903, the younger son of Bepin Behari Basu. The boy was brought up in a disciplined atmosphere under the strict attention and guidance of his parents. He had his early education in the Madaripur High School whence he passed his matriculation examination in 1920. After passing I.Sc. from the City College, Calcutta, he joined the Scottish Church College, Calcutta, for his B.Sc. degree. Later, he took his M.Sc. degree in Chemistry from the University of Calcutta in 1926, standing first in first class. During these years he was inspired by Sir P. C. Roy and Prof. H. K. Sen and continued his research in Chemistry as a Scholar of the University. He received his D.Sc. degree in 1935. Basu had a brilliant academic and research career. He received in 1928 the '*Rash Behari Ghosh Scholarship*' in Applied Chemistry of the University College of Science, Calcutta. He secured the '*Nagarjuna Prize*' and a '*Gold Medal*' for the best piece of research work in chemistry in 1930, the '*Griffith Prize*' in 1930 and the '*Sir Asutosh Mukherjee Gold Medal*' in 1931. Subsequently, for his researches on the synthesis of certain nitrogenous ring systems as found in Nature, he was awarded the coveted '*Premchand Roychand Scholarship*' in 1936 and the '*Mount Medal*' in 1938.

PROFESSIONAL CAREER

Dr. Basu began his professional career as a temporary teacher in the Department of Chemistry, University College of Science and Technology in 1931 and was later Research Fellow and Honorary Lecturer. Subsequently, as advised by Sir P. C. Ray, he joined the Bengal Immunity Co. Ltd. as its Chief Chemist and Officer-in-Charge of its Research Laboratory. Here, he came in contact with the then Managing Director of the Company, Captain N. N. Dutta who was a man of great vision and a high exponent of the Indian Pharmaceutical Industry. Realising the importance of research for the development of the Industry, Captain Dutta



W. B. P. m.

founded the Bengal Immunity Research Institute in 1947 and specially assigned to young Basu the functions and responsibilities of its Director. Here, Basu was able to initiate investigations into various aspects of 'Drug Research' and was able to make, in collaboration with his colleagues, significant contributions to pharmacy chemotherapy, and pharmaceutical and industrial chemistry. It was with Basu's initiative that B.I. Research Institute soon developed into an important centre for 'Drug Research' where devoted research workers could pursue their scientific investigations in a calm and peaceful atmosphere with all possible facilities at their disposal. With the whole hearted cooperation, advice and assistance of his colleagues like the organic chemist T. N. Ghosh, the biochemist G. C. Esh, and the pharmacologist. A. N. Bose, Dr. Basu could raise the standard of research to such a high level that the Govt. of India recognized the B.I. Research Institute as a centre for higher training and research in synthetic organic chemistry, pharmaceutical chemistry, biochemistry and nutrition and pharmacology.

Impressed by Dr. Basu's activities at the Bengal Immunity Research Centre, Dr. S. S. Bhatnagar, the then Director-General of the CSIR, initiated a Research Project on '*Antimalarial Compounds*' under the leadership of Dr. Basu, in 1951. Later, in 1952, five more CSIR schemes were sanctioned to the BIRI as a recognition of his leadership qualities. Subsequently, these schemes were amalgamated into a 'Chemotherapeutic Research Unit' at the BIRI with Dr. Basu as its Investigator-in-Charge.

Dr. Basu's efforts led the Institute to be recognised as a centre for advanced research by the Universities of Calcutta, Jadavpur and Panjab. Many workers at the Institute guided by him received doctorates from the Calcutta University.

CONTRIBUTION TO SCIENCE

Dr. Basu's researches cover a wide field. His work may be classified under the heads: (i) Synthetic Organic Chemistry, (ii) Drugs and Chemotherapy (Antimalarials, Antitubercular, Antispasmodic and Antifilarial compounds, Organometallic and Organo-therapeutic compounds, Pharmaceuticals, Plant Products etc.; (iii) Analytical chemistry; (iv) Industrial problems; and (v) Reviews. His 300 original scientific papers and more than 100 reviews amply testify to Dr. Basu's versatility and encyclopaedic knowledge in the fields of science, education, research and industry.

Synthetic Organic Chemistry

During his early research career, Basu synthesised some Bz-hexahydro-isoquinolines. He adopted the Guareschi synthesis of pyridines and its modification by Knoevenagel and Fries to the synthesis of Bz-hexahydro-isoquinolines. In the first example, ethyl cyclohexanone carboxylate was condensed with cyanoacetamide to yield a bz-hexahydro-isoquinoline derivative. In the second example, oxymethylene cyclohexanone was treated with ammonia and the resulting aminomethylene compound condensed with ethyl aceto-acetate in the presence of sodium. The resulting substance on hydrolysis yielded the corresponding acid, which was

easily decarboxylated and converted into isoquinoline by distillation with zinc dust. This constitutes a novel method of synthesis of isoquinoline derivatives and assumes importance in view of the fact that many alkaloids occurring in Nature are found to be isoquinoline derivatives, some of which possess medicinal properties.

6-Methyl-2:3 dihydro- β -pyridindine, which can be regarded as a derivative of the hypothetical compound termed β -pyridindine in analogy with β -quinindene has been synthesised and this constitutes synthesis of a new ring system. A new method of synthesis of 1:2 diaminopropionic acid derivative has been achieved. The action of zinc on ethyl alpha-bromohippurate has yielded an oxazine derivative, the hydrolysis of which leads to the formation of 1:2-dibenzamidopropionic acid. The latter acid responds to Dakin-West reaction and eliminates carbon dioxide when reacted with benzoyl chloride in presence of pyridine, yielding α - β -dibenzylaminopropiophenone. Subsequently, Basu carried out extensive investigations on the synthesis of acridine, isoquinolines, quinolines, quinolizines, phenanthridines, piperazines, triazines, triazoles and some heterocyclic biguanides and sulphonyl urea derivatives with diverse pharmacological activities. Towards the end of his career, he became interested in the synthesis of a class of compounds by linking isoquinoline ring with a quinoline moiety some of which have shown pronounced antiprotozoal as well as spasmolytic properties.

Drugs and Chemotherapy

Extensive researches, directed towards development of potent antimalarials have been carried out by Basu and his collaborators. The work which began in 1937 dealt at the outset with the synthesis of a large number of new acridine derivatives some of which are structurally related to Atebrine. Further work was carried out on the synthesis of 8-aminoquinoline derivatives as possible antimalarials. A few in this series were already known, such as plasmoquine, pentaquin etc. and although they have curative properties in malaria, possess undue toxicity. As such, efforts were directed towards synthesis of some more effective products by altering the side alkylamino chain, retaining the basic character of 8-aminoquinoline unchanged in plasmoquin. A large number of derivatives were synthesised in the laboratory. One compound, compound 'C', which is chemically 7-chloro-4-(4'-hydroxy-3°-diethylaminomethyl) anilino-2-methylquinoline, possesses significantly high antimalarial activity and on the basis of clinical trials, a patent on compound 'C' was granted. In another scheme on the synthesis of 'New Antispasmodics in the Isoquinoline Series', Dr. Basu and his collaborators successfully synthesised the "Compound AI57" which is N, N-bis-(3-methyl-1-isoquinoly)- α -methyl- β -phenethylamine triphosphate possessing pronounced antispasmodic activity. The investigation on sulphonamides has revealed that acetylation of the amide grouping of *p*-aminobenzene sulphonamide considerably widens the activity of sulphanilamide's therapeutic efficacy of sulphaninyl benzamide in bacillary dysentery.

Basu's works on the isolation and structural elucidation of the plant principles from (i) *Centella asiatica* (Isothankunic acid, thankunic acid, Asiatic acid, than-

kuniside and isothankuniside) and (ii) *Bacopa monniera* (Monnierin) and ephedrine from *Sida* species deserve special mention. The synthesis of some aryl sulphonamido-1, 2, 4-triazoles, phenyl semicarbazides and substituted thiosemicarbazides and their transformation to certain 5-membered heterocycles was carried out with a view to finding out a suitable oral antidiabetic drug. The compound AF23, (N-Diethyl carbamyl-4'-biguanide piperazine hydrochlorids and AF85 Piperidino-carbamyl piperizing hydrochloride) synthesised by Basu and his collaborators was found to be promising as filaricide. He made some significant contributions in plant chemistry by isolating pharmacologically active principles from *Rauwolfia serpentina* and active principles containing hyoscyamine and those known to contain antifertility principles. In the study on organometallic series attention was directed towards gold, silver and bismuth compounds. The sodium bisulphite derivatives of the Schiff's bases from sodium arsenates have been found to be more stable and less toxic than atoxyl.

SERVICE TO PHARMACEUTICAL INDUSTRY AND LEARNED SOCIETIES

Dr. Basu contributed significantly to the development of various pharmaceuticals required in the industry. Some of them may be mentioned here: (a) newer methods of formulations such as Protein Hydrolysate Injection, Adrenaline Malate Injection, Fat-soluble vitamins in stable aqueous media, and others; (b) standardisation of Hydnocarpus oil, groundnut oil, glycerine, activated charcoal, ethyl oleate; (c) postulation of norms and standards of containers for pharmaceutical use by glass manufacturers; and (d) technical know-how for the large-scale manufacture of drugs like chloroquin phosphate, Isonicotinic hydrazide, Phenformin hydrochloride, Antacids (Magnesium trisilicate, Magnesium hydroxide), Calcium lactobionate and others.

Dr. Basu's work on the stability of vitamin A acetate in solution has helped in the fixation of International standard. His synthetic work on acridine, iso-quinoline and quinoline derivatives has been quoted in standard reference books. His significant contributions to antimalarials, sulphas and antidiabetics brought Dr. Basu to international recognition. His work on the side products in the largescale production of chloroquin and isoniazid was particularly important.

Dr. Basu contributed significantly to the development of pharmaceutical industry in India. He was Member of the Drugs Technical Advisory Board, Ministry of Health for 18 years and was in the Defence Council (Chemical) during World War II. The Ministry of Health nominated him as Member of the Indian Pharmaceutical Delegation to Europe and the U.S.S.R. in 1955. He was also Member of the Indian Counterpart team of the Russian Delegation for establishment of the Indian Pharmaceutical Industry and of the Drugs and Equipments Standard Committee in 1963. In the Council of Scientific and Industrial Research, he was Member of the Malaria Chemotherapy Committee as well as of the Drugs and Pharmaceutical Research Committee. He was a Member of the Development Council of Drugs and Pharmaceuticals, Ministry of Commerce and Industry, Government of India,

of the Indian Council of Technical Education and the Scientific Board of the National Council of Education and Research, Ministry of Education, Govt. of India. He was also Member of the Governing Body of the Central Drugs Research Institute, Lucknow.

Dr. Basu played an active part in the development of Scientific Institutions, Societies and Organisations in India and was also associated with a number of similar societies in U.K. and U.S.A. He served the Indian Chemical Society as a Member of the Council and Board of Associate Editors and also as its Vice-President. As Secretary (for 17 yrs) and President of the Institution of Chemists of India, he worked for the recognition of the Associateship as equivalent to M.Sc. by the Ministry of Education, Government of India and thereby provided opportunities to Indian Science graduates for developing their professional careers. Dr. Basu was Vice-President of the Indian Association for the Cultivation of Science.

Dr. Basu was a Member of the Governing Bodies of the ICMR and the Indian Statistical Institute and of the Advisory Board of the Indian Institute of Technology, Kharagpur. He was President of the Science Club of India and the Indian Pharmaceutical Association and Vice-President of the Indian Association for the Cultivation of Science and Immunity Scientific Association. He presided over the Chemistry Section of the Indian Science Congress in 1952-53 and served the Association as General Secretary for four years and during this tenure he moved for the registration of the Association and for its permanent Headquarters and Office buildings. He was Chairman of Pharmaceuticals and Fine Chemicals Sub-Committee. He was a Member of: 1) The 'Chemistry Sub-Committee' of the Indian Pharmacopoeia Committee; 2) The 'Chemical Planning Committee' of the Planning Commission (1963); 3) 'Chemical Division Council' of the Indian Standards Institution; and 4) the Asiatic Society, in the Council of which he served for many years.

He served the West Bengal Government as a Member of: 1) Board of Industries; 2) State Pharmacy Council; 3) Medicinal Plants Committee, etc.

Dr. Basu also served as the Editor of the '*Chemical Industry News*' of the Indian Chemical Manufacturers Association as Editor-in-Chief of the '*Journal of Science Club*' and in the latter capacity he tried to popularise science through his writings.

HONOURS AND AWARDS

In recognition of his scientific achievements, Dr. Basu was awarded the '*Barclay Medal*' (Asiatic Society), '*H. K. Sen Memorial Medal*' (Institution of Chemists of India) and '*Acharya P. C. Ray Memorial Medal*' (Indian Pharmaceutical Association). He was President of the Indian Pharmaceutical Congress, 1969.

HIS QUALITIES

Dr. Basu was always full of vitality and energy. It is true to say that his life was varied, active and a very happy one. He was a man of great personal charm and

simple dignity. His warm, friendly humour endeared him to every one and his friends will remember him for his generosity and good companionship. He had an astonishing memory and to the end he remained physically and mentally alert.

He is survived by his wife, one son and four daughters.

G. C. ESH

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KRAMADHATI VENKATA GIRI

(1907-1958)

Elected F.N.I. 1956

BIRTH, PARENTAGE AND CHILDHOOD

KRAMADHATI VENKATA GIRI was born in the year 1907 in a remote village near Madanapalle in Andhra Pradesh where his father, Shri K. Surappa lived. Giri at a very young age ventured out of his village to Madanapalle for his early education.

FORMATIVE INFLUENCE ON THE YOUNG SCIENTIST

As a young student in the Madras University, Giri set for himself high standards of morality and dedication in achieving his goals, preparing himself to obtain the best possible education to enable him finally to become one of the leading biochemists of his time.

SCHOOL AND UNIVERSITY EDUCATION AND RESEARCH

Giri obtained the B.A. degree of the Madras University from the St. Joseph's College, Tiruchirappally. He took the M. Sc. degree of the University of Calcutta and then joined the Department of Biochemistry, Indian Institute of Science, Bangalore in 1929. His early work on 'Investigations on Enzymes' gained for him the degree of Doctor of Science of the Calcutta University in 1938.

PROFESSIONAL

After two years of service as Enzyme Chemist at the Nutritional Research Laboratories, Coonoor (1939-40) and three years as Gowthami lecturer and later Reader in Biochemistry at the Andhra University, Dr. K. V. Giri returned to the Institute at Bangalore to become a lecturer in Biochemistry in 1943. He was elevated in 1950 to the Professorial Chair in Biochemistry, a post he held till the end. During 1949-50, Prof. Giri was associated with Prof. H. von Euler at the University of Stockholm, Sweden and visited Norway, Denmark and England. He presided over a session of the International Symposium on '*Enzyme Chemistry*' held in Tokyo in the autumn of 1957. Prof. Giri was actively associated with executive and advisory committees of several universities, research institutions and technical bodies, both in India and abroad.

Till the very end, Prof. Giri was greatly devoted to science and in the spread of biochemical knowledge for exploitation of abundant vegetable and animal



K. V. Guin

resources. He held the firm conviction that to achieve this end, economical and highly simplified biochemical techniques are necessary pre-requisites. He spared no pains to popularise these techniques through his writings, lectures, radio-talks visual demonstrations by charts and cine films. He took great delight in assiduously collecting photographs and life sketches of famous scientists, particularly, Nobel Laureates. His chief pleasure was in the laboratory where he preferred to work himself rather than to entrust to others. Until his passing away, he had great admiration for his colleagues and students all of whom he treated with extreme affection in the laboratory and his home

The sudden demise of Prof. Giri on 17 July 1958 in Madras took away from our midst a well-loved personality and a distinguished biochemist of our country.

CONTRIBUTIONS TO NEW KNOWLEDGE

Water-soluble vitamins

Thiamine (Vitamin B₁): A simple and rapid method for the estimation of vitamin B₁ in foodstuffs was developed and the amounts of this vitamin in ground-nut, during germination and under different conditions of manuring, were estimated. Investigations were also carried out on its biosynthesis in molds and by the intestinal flora of rats under different dietary supplements like milk, curds, fats or on the administration of sulphaguanidine, *p*-aminobenzoate and penicillin.

Biotin: It was shown that administration of excess amounts of biotin to rats leads to an increased synthesis and accumulation of cholesterol in tissues and that these effects could be reversed by giving inositol.

Ascorbic Acid: Giri's studies on the analytical chemistry of ascorbic acid and on its stability under varying environmental conditions, are also worthy of mention. The mechanism of the inhibitory action of ascorbic acid on important enzymes like amylases and phosphatases was also investigated.

Riboflavin (Vitamin B₂): Of considerable interest is his observation that a mutant of yeast, *Saccharomyces cerevisiae*, excreted considerable amounts of this vitamin into the medium. This work on riboflavin eventually led to extensive investigations on the flavin coenzymes.

Enzymes

Professor Giri was a pioneer in enzyme research and his earliest studies were concerned with purification and documentation of the properties of some key enzymes in intermediary metabolism, viz., phosphatases, amylases, lipases and proteases. Much of this work was published in *Zeitschrift fur Physiologische Chemie*, *Biochemische Zeitschrift*, *Biochemical Journal*, *Nature* and *Enzymologia*.

Carbohydrate Metabolism

A systematic search for phosphorylase in Indian pulses showed that green gram was a good source of the enzyme. The enzyme was purified and its nature and behaviour towards various substances of biological importance were studied. A method was developed for the preparation of glucose-1-phosphate, using green

gram extract as a source of phosphorylase. In addition to phosphorylase, another enzyme with the branching factor or Q enzyme which takes part in the synthesis of starch was isolated from green gram and its characteristics were studied.

Evidence in support of the existence of Embden Meyerhof glycolytic pathway in green gram was advanced through identification and isolation of all the enzyme systems involved. Phosphorylated glyceric acids were shown to be very effective precursors for sucrose synthesis in green gram.

An enzyme capable of building up glucofructosans from sucrose was detected in water extracts of the tubers of *Crinum longifolium* and *Crinum latifolium*. It was concentrated and purified from associated carbohydrates and its characteristics were determined. Normally, sucrose acts as the acceptor as well as the donor of fructosyl residues. Raffinose also was found to act as a substrate; it builds up two oligosaccharides when acted upon by this enzyme. It was shown that neither glucose nor fructose acts as an inhibitor.

The penicillin producing strain *P-chrysogenum* Q 176 was capable of synthesizing various types of oligosaccharides when grown in a medium containing maltose and sucrose. Enzymes capable of synthesizing these oligosaccharides were prepared in pure form by passing through starch column and by subsequent alcohol precipitation. All the oligosaccharides synthesized from maltose were identified and characterized by means of periodate oxidation, physical constants, mobility on paper chromatograms and by comparison with acid hydrolysates of known polysaccharides.

Nitrogen Metabolism

A systematic survey of the free amino acid content of several edible leaves and leaves of the citrus family was made. Citrus leaves contain a good percentage of proline. A high concentration of asparagine was observed in betel leaves. Hydroxyproline was found to occur in the leaves of sandal in high concentrations; the flowers and pericarp contained the highest percentage. This amino acid was isolated by a combination of ion-exchange and circular paper chromatography and was characterized by physical and chemical methods as allo-hydroxy-L-proline. This is the first report of free hydroxyproline in the plant kingdom.

Cell-free extracts of green gram were found to synthesize glycine from a variety of amino acids by transamination with glyoxylic acid.

Partial purification of the enzyme, arginase, from field beans (*Dolichos lablab*) was effected and the kinetics of metal ion activation was studied. The enzyme activity was unaffected by copper and cadmium, but was inhibited by borate, citrate, cystine, ornithine and lysine. The presence of transaminases, viz., glutamic acid-alanine and glutamic acid-aspartic acid, in some of the Indian pulses was detected by paper chromatography. The glutamic-aspartic transaminase was inhibited by pterygospermin, an antibiotic isolated from the roots of the drumstick tree (*Moringa pterygosperma*).

An enzyme which converts riboflavin to flavin mononucleotide (FMN) was purified from green gram extracts, with a recovery of about 40%. The conversion of riboflavin to FMN was nearly 60%.

An enzyme which hydrolyses flavin adenine dinucleotide (FAD) to FMN and adenosine-5'-phosphate (AMP), was obtained in crystalline state from green gram seedlings. Its optical pH was 9.0–9.4. At the ammonium sulphate stage of purification and on treatment with glutathione (GSH), this enzyme gave riboflavin, pyrophosphate and adenosine. This alteration of the site of attack is inhibited by phosphate ions. Further, the inhibition of the original activity (i.e., FAD to FMN and AMP) together with a change in the spectrum of the enzyme, on the addition of phosphate indicates the key role played by phosphate ions in this activity.

The FAD hydrolase was purified 300-fold from germinating seedlings of green gram. It was inhibited by EDTA and the inhibition could be reversed only by Zn^{2+} and Co^{2+} ions. Zinc ions at concentrations above 1×10^{-4} M inhibited the EDTA-treated as well as the untreated enzymes. This effect of Zn^{2+} ions is similar to that observed in the case of well-known regulatory enzymes which are inhibited either by excess substrate or co-factor. Similarly, this enzyme was inhibited by pyrophosphate, ATP and AMP, EDTA and activation of the EDTA-inhibited enzyme by Zn^{2+} followed a typical allosteric pattern.

AMP is an allosteric inhibitor for the crystalline FAD-hydrolase from mung bean (*Phaseolus radiatus*). One of the sites of AMP inhibition could be desensitized by P-chloromercuri-benzoate (PCMB) or N-ethyl maleimide or by ageing. A partially inactivated enzyme could be reactivated by low concentrations of adenosine diphosphate (ADP).

Riboflavin Metabolism in Plants

It is well known that the B-vitamins occur abundantly in higher plants. With the demonstration that some of the B-vitamins like nicotinic acid and riboflavin function as components of enzymes, increasing attention was devoted to the study of the role of these vitamins in plants. Investigations were carried out on the forms in which riboflavin occurs in plants and on the enzymatic synthesis of the flavin coenzyme nucleotides.

Starting with riboflavin, FMN is synthesized by the enzyme flavokinase by an irreversible reaction with ATP. The partially purified (75-fold) enzyme functions optimally at a temperature of 55 °C and pH 8.6. The high temperature optimum, although very unusual for enzymes in general, is not uncommon in plants. The substrates (riboflavin and ATP) exert a protective action against heat denaturation and this would, to a certain extent, explain the activity at high temperature. It is highly specific for the flavin, but not so specific for the phosphate donor.

FAD is synthesized from FMN and ATP and this reaction is catalysed by the enzyme, FAD synthetase, which functions optimally at a temperature of 37 °C and pH 7.5. The 83-fold purified enzyme is specific for its substrates FMN and ATP, and it showed some hydrolytic activity which was very much less than that of the crude extract; this suggested the possibility that in addition to the hydrolysis by the reversal of FAD-synthetase, FAD may also be hydrolysed by a specific enzyme.

Studies on Blood Coagulation

Prof. Giri was one of the leading research workers of his time who initiated a systematic study of the mechanism of blood coagulation. His painstaking work on the separation of various protein factors involved in blood coagulation, the study of their interactions and the isolation of anti-coagulant factors from indigenous plant sources, represented his major work in this area.

Paper Chromatography

Prof. Giri and his associates made important contributions to the development of paper chromatography as a powerful tool in biochemical research. Particular mention may be made of the development of a paper chromatographic technique for the separation and identification of enzymes, for the qualitative and quantitative analysis of a variety of biochemically important compounds like amino acids, sugars, organic acids, etc.

It was shown that enzymes could be made to move on paper employing aqueous acetone or alcohol or salt solutions as the developing solvents. The position of the enzymes on the developed chromatograms was located by the agar plate method.

The circular paper chromatographic technique developed by him has proved to be a simple, elegant and rapid method for the separation and identification of many biological metabolites. The wide application of this method in diverse fields is indicative of its advantages, in certain respects, over the conventional methods.

Agar Electrophoresis

Prof. Giri and his colleagues also developed a simple technique of agar electrophoresis for the separation of serum proteins. In this modification of the well-known paper electrophoresis method, the filter paper is replaced by agar gel layered between glass plates, as the medium. The method is simple, quick and efficient in the resolution of protein components without adsorption. Further, this technique affords the separation in the serum of a larger number of components than those obtained by paper electrophoresis.

A simple method of two-dimensional agar electrophoresis was developed by which mucoproteins could be separated into well-defined zones. The mucoprotein spots could be identified by fuchsin sulphate spray after periodate oxidation. This technique is useful for the examination of the changes in mucoproteins in pathological samples of blood and urine.

Prof. Giri felt the need to spread biochemical knowledge widely and made a hobby of devising scientific films. He wanted every medical practitioner in India to have access to clinical biochemical services and this objective was stressed through his films, writings, radio talks and lectures.

MARRIAGE, WIFE AND PRIVATE LIFE

Prof. Giri married the daughter of Shri H. Krishna Sastri, the first Indian Chief Epigraphist to the Government of India. His wife, Smt. Janakamma took a deep

interest in his work and helped to translate many of his publications into Telugu and Kannada.

Prof. Giri has four children, two sons and two daughters. His eldest son, Dr. K. V. Ravi, has specialised in material science and is now working as the Technical Director of MOBILE-TYCO laboratories in U.S.A. and is directing research programmes in the area of solar energy. His second son Shri K. V. Chandrasekhar, is Managing Director of M/S. Sekhar Electronic Industries Pvt. Ltd., a company engaged in the manufacture of electronic components in Bangalore.

His first daughter, Smt. Usha is a qualified Chartered Accountant and his second daughter, K. V. Amba is a Computer Scientist.

N. APPAJI RAO

C. S. VAIDYANATHAN

H. R. CAMA

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SUBBARAMIAH MINAKSHISUNDARAM

(1913-1968)

Elected F.N.I. 1958

SUBBARAMIAH MINAKSHISUNDARAM was born in Trichur, Kerala State, on October 12, 1913. His father was a sanitary engineer. Minakshisundaram had his early education in Madras at the Cunniah Chetty High School. After passing the High School examination in 1929, he joined the Pachaiyappa's College, Madras, for the Intermediate and then the Loyola College, Madras, for the B.A.(Hons.) in Mathematics. The Loyola College was, even in those days, well known for 'producing first classes' at the University examinations and sure enough, young Minakshisundaram, who had shown marked aptitude for mathematics both at High School and College, obtained in 1934 a first class in the Madras University examination.

RESEARCH CAREER IN MATHEMATICS

Unlike many brilliant young men of that time, Minakshisundaram, or Minakshi as he was called by his more intimate friends, desired to study Mathematics more deeply and take to it as a career instead of going in for the administrative service which was more lucrative and prestigious. He was initially influenced by Professor K. Ananda Rau, and as a Research scholar of the Madras University, began a study of the problems of summability of series. His passion for summability never left him and significantly his first and last papers were on problems of summability.

As a research student young Minakshi showed his mettle. His early papers on Tauberian theorems and summability revealed his quick understanding of classical Fourier analysis. Even in his first paper, Minakshisundaram (1936-37) not only proved a theorem more general than that of Ananda Rau (*Proc. London Math. Soc.*, (2) **34** (1931) 414-440) by a method different from Ananda Rau's but as Hardy (1949) points out (p. 146-147), Minakshisundaram removed the restriction in Ananda Rau's proof. However, the really challenging problems came to him from different sources. In 1937-38, Fr. C. Racine had just come to India from Paris, having been trained in the famous French School in Analysis. He was invited by the Madras University to give a course of 'extension lectures'. Fr. Racine lectured on non-linear partial differential equations and especially on the

Note: INSA expresses its thanks to Dr. P.C. Jain, Secretary, Indian Mathematical Society for giving permission to reprint this article with minor modifications.



S. M. Maheshwaram.

work of Giraud and Gevrey. At about the same time Minakshi met Professor M.R. Siddiqui of the Osmania University, Hyderabad, who had studied with Lichtenstein in Berlin and had written a thesis on non-linear parabolic and hyperbolic equations. Minakshisundaram's (1938, 1939) early papers written under the influence of Siddiqui, carried on where Siddiqui had left and displayed an analytical finesse of a high order. The method of Siddiqui and Lichtenstein, say for the parabolic equation (the same holds for hyperbolic equations)

$$\begin{aligned} \frac{\partial}{\partial x} \left(\rho(x) \frac{\partial u}{\partial x} \right) - \frac{\partial u}{\partial t} &= f \left(x, t, u, \frac{\partial u}{\partial x} \right), \\ u(x, 0) &= u_0(x), \\ u(0, t) = 0 &= u(\pi, t), \quad t \geq 0, \end{aligned} \quad \dots (1)$$

consists essentially in looking for a solution of the type

$$u(x, t) = \sum_n u_n(t) \phi_n(x), \quad \dots (2)$$

where $\{\phi_n(x)\}$ are the eigen functions of the associated Sturm-Liouville problem

$$\begin{aligned} \frac{d}{dx} \left(\rho(x) \frac{d\phi}{dx} \right) + \lambda \phi &= 0, \\ \phi(0) = 0 &= \phi(\pi), \end{aligned}$$

and assuming that f can be expanded in terms of $\{\phi_n(x)\}$. If one inserts (2) in (1), one obtains an infinite system of non-linear integral equations which are solved by the method of successive approximations. The results obtained by Minakshi were neither routine generalisations nor simple ones and go far beyond the work of Siddiqui and Lichtenstein. At the suggestion of Fr. Racine, Minakshisundaram studied the topological methods of Schauder and Leray and by an application of their fixed point theorem, proved the existence, and in some cases uniqueness, of solutions of non-linear partial differential equations of the parabolic type. These results are extremely beautiful and formed part of his doctoral dissertation submitted to the Madras University, entitled '*Fourier Ansatz and Non-linear Parabolic Equations*'. This thesis is perhaps one of the best D.Sc. theses of the Madras University.

The thesis led to the study of a new summation process which he called Bessel summability. This method of summation was interesting in itself and also served to unify and, in some cases, extend known methods of summability. He himself only gave (Minakshisundaram 1943) 'a few elementary results' concerning Bessel summability of series. The detailed study of a special type of Bessel summation was undertaken by K. Chandrasekharan in his M.Sc. thesis of the Madras University (1942) and later by M.S. Rangachari (*Math. Zeit.*, **88** (1965), 166-183 and *ibid* **102** (1967), 245-252). Another important outcome of his thesis is the long series of papers (cf. Minakshisundaram 1940, 1941, 1942, 1943) on eigen-function expansions. Here Minakshisundaram brought to bear on a new domain his mastery

of classical analysis of convergence and summability of Fourier series and demonstrated his ability to adapt and generalise them. Consider, for instance, the boundary value problem

$$\Delta u + \lambda u = \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \lambda u = 0, \quad \dots (3)$$

$$u(x, y) = 0 \text{ on } C, \quad \dots (4)$$

where $u(x, y)$ is a function on a bounded plane domain D bounded by a piece-wise regular curve C . Let $\lambda_1 \leq \lambda_2 \leq \dots \rightarrow \infty$ be the series of eigen-values and $\omega_1(x, y)$, $\omega_2(x, y) \dots$ the corresponding series of normalised orthogonal eigen-functions. Let $f(x, y)$ be a function Lebesgue integrable in D and let

$$a_n = \iint_D f(x, y) \omega_n(x, y) \, dx dy$$

be the 'Fourier coefficients' of $f(x, y)$ and

$$f(x, y) \sim \sum_n a_n \omega_n(x, y) \quad \dots (5)$$

the 'Fourier eigen-function series' of $f(x, y)$. Minakshisundaram then asks about (5), questions similar to that one asks concerning classical Fourier series and begins answering them, to the extent possible, in this series of papers. A well-known theorem (Courant & Ailhert 1953) asserts that if f is continuous on $D + C$, vanishes on C and if the second partial derivatives of f are square integrable in D , then the right side of (5) converges to f absolutely and uniformly. Minakshisundaram proved that if $\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}$ exist almost everywhere on D and are square integrable, then (5) converges to $f(x, y)$ at all points of continuity of f in D . This resembles the well-known Fatou's theorem in Fourier series. A paper on the expansion in eigen-functions of boundary value problems II, of this series is very interesting and is devoted to Riesz summability of eigen-function expansions. In it Minakshi proves, among others, that if $f(x, y)$ is continuous on $D + C$ and vanishes on C then (5) is summable (R, μ, k) for $k > \frac{3}{2}$; here $\mu_n = \lambda_n^{1/2}$. The results, but not the methods, of the paper formed part of an essay for which Minakshisundaram was awarded the '*Ramanujan Memorial Prize*' of the Madras University in 1942. In other papers of this series he discussed problems like 'When $\sum_n a_n \omega_n(x, y)$ is the Fourier eigen-function series of a Lebesgue integrable function' or problems concerning absolute convergence etc. He observed finally, that the restriction to problems in the plane is unnecessary and that the results could, with suitable modifications, be upheld in R_n for $n \geq 2$. Some years later in the note titled, "A uniqueness theorem for eigen-function expansions" he discussed the problem of uniqueness of eigen-function expansions employing the technique of sub-harmonic functions. The whole complex of these papers reveal high technical virtuosity.

After taking the D.Sc. degree of the Madras University in 1940, Minakshisundaram was stranded without a job. He was offered a university job on a miserable salary, but he rejected it because, as he said, no self-respecting scientist could accept the humiliation of being paid like a porter at a railway station. He felt very frustrated, but due to the timely assistance of Fr. Racine who was professor at Loyola College, he could earn some money by coaching a few students of that college for the university examinations. Such things seem incredible now-a-days, but in those days (during the forties) research was still considered a parlour game and only administrative positions were sought after by young talented men. That Minakshi should have stood so steadfastly for a career in mathematics even under such adverse conditions redounds to his greatness—a greatness that can be understood and appreciated only by those who have known the hard conditions, during the years preceding and following the Second World War, for those aiming at intellectual achievements.

It was during these years that Fr. Racine and Minakshisundaram organized the weekly Mathematics Seminar—a new thing in Madras at that time—in which many, including Chandrasekharan, the present writer and a few others participated. Minakshi's work by this time had attracted the attention of mathematicians in England and the U.S.A. Meanwhile he was appointed a lecturer in the Department of Mathematical Physics at the Andhra University and he felt relieved.

HIS RESEARCH CAREER AT PRINCETON, U.S.A.

Shortly afterwards, in 1946, due to the efforts of Fr. Racine and the interest evinced by Professors M. H. Stone of Chicago University and Professor Marston Morse of the Institute for Advanced Study, Princeton, Minakshi was offered a Membership at the famous Institute. He arrived in Princeton not merely with a very sound knowledge of mathematics, but with an exceptionally sharp and clear mind capable of attacking important problems. Contacts with Professors Weyl, Siegel and Pleijel brought out the best in Minakshisundaram. He stayed in Princeton for two years and his work there may, perhaps, be called his best work. His knowledge of classical Analytical Number Theory, and the interaction with Weyl and Pleijel resulted in a beautiful and important work by Minakshisundaram and Pleijel.

HIS CONTRIBUTIONS TO MATHEMATICAL KNOWLEDGE

Minakshisundaram observed that if one considers the plane boundary value problem

$$\begin{aligned}\Delta u + \lambda u &= \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \lambda u = 0, \\ u(x, 0) &= u(x, 2\pi), \frac{\partial u}{\partial x}(0, y) = \frac{\partial u}{\partial x}(2\pi, y), \\ u(0, y) &= u(2\pi, y), \frac{\partial u}{\partial y}(x, 2\pi) = \frac{\partial u}{\partial y}(x, 0),\end{aligned}$$

then the eigen-functions are $\phi_N(x) = e^{i(n\alpha + m\beta)}$ and the eigen-values are $\lambda^N = n^2 + m^2$, $N = [n, m]$, n, m being integers. If, therefore, we form the function

$$Z(s) = \sum_{n,m} \frac{\phi_N(x) \phi_N(x')}{\lambda_N^s},$$

then $Z(s)$ is precisely an Epstein zeta function. Minakshisundaram therefore considered the 'zeta function' of the membrane problem

$$\begin{aligned} \frac{\partial^2 u}{\partial x_1^2} + \dots + \frac{\partial^2 u}{\partial x_k^2} + \lambda u &= 0, \\ u(x_1, \dots, x_k) &= 0 \\ \text{or } \frac{\partial u}{\partial n}(x_1, \dots, x_k) &= 0 \end{aligned} \left. \vphantom{\begin{aligned} \frac{\partial^2 u}{\partial x_1^2} + \dots + \frac{\partial^2 u}{\partial x_k^2} + \lambda u &= 0, \\ u(x_1, \dots, x_k) &= 0 \\ \text{or } \frac{\partial u}{\partial n}(x_1, \dots, x_k) &= 0 \end{aligned}} \right\} \text{ on } C,$$

where C is the boundary of the domain, D , $\frac{\partial u}{\partial n}$ being the normal derivative. Having the eigen-functions and the eigen-values, one can write the 'zeta function'

$$Z(s) = \sum_n \frac{\phi_n(P) \phi_n(Q)}{\lambda_n^s},$$

where P and Q are two points of D . Elementary estimates show that $Z(s)$ has a finite abscissa of convergence. With Riemann's ideas regarding the classical zeta function before him, Minakshisundaram began the study of the function $Z(s)$ and to use it for studying not only the asymptotic distribution of eigen-values, a problem initiated by Hermann Weyl, but also the more difficult problem of determining the asymptotic distribution of the eigen-functions on which T. Carleman and later A. Pleijel did such pioneering work. Unlike Carleman, Minakshisundaram used the Green's function of the heat equation $\Delta u - \frac{\partial u}{\partial t} = 0$ as the analogue of the 'theta function'. Application of Tauberian arguments led to generalisation of Carleman's asymptotic results. As Hermann Weyl (1950) remarked, Minakshisundaram '*working independently of Carleman, had found a modification of Carleman's method, shedding a new light on the whole problem.*'

With Pleijel he now studied the more general problem of eigen-values and eigen-functions of the Laplace-Beltrami operator associated with a positive fundamental metric on an analytic Riemannian manifold V of dimension N . They proved (Minakshisundaram & Pleijel 1949) that

$$Z(s) = \sum_n \frac{\phi_n(P) \phi_n(Q)}{\lambda_n^s},$$

where P and Q are two points of V , can be continued analytically into the whole s -plane as an entire function of s with zeros at non-positive integers if $P \neq Q$ and as a meromorphic function if $P = Q$, Tauberian arguments give

$$\sum_{\lambda_n < T} \phi_n^2(P) \sim \frac{T^{N/2}}{(2\sqrt{\pi})^N \Gamma(N/2 + 1)},$$

$$\sum_{\lambda_n < T} 1 \sim \frac{V_0 T^{N/2}}{(2\sqrt{\pi})^N \Gamma(N/2 + 1)},$$

where V_0 is the volume of the closed manifold V .

This paper, which is perhaps one of the most quoted of Minakshi's papers, generalises and extends the work of Carleman. The ideas in this paper, and in Minakshisundaram's other papers have been used and also generalised by several authors. R. Seeley has defined complex powers of an elliptic operator and it turns out that its trace resembles the 'zeta function' of Minakshisundaram and Pleijel. Its relation to the index formula of Atiyah-Bott (1967) is one of the highlights of present-day Analysis and Topology (see Atiyah and Bott 1967) especially pages 403-404). The connection with Pseudo-differential operators is given in Hörmander (1968).

Recently, McKean and Singer (1967) have studied, in a more general setting the fundamental solution of the heat equation which Minakshisundaram (1943) had used. They derive important results concerning what they call the '*Minakshisundaram Coefficients*'. If one considers the Laplacian

$$\Delta u = \frac{\partial^2 u}{\partial x_1^2} + \frac{\partial^2 u}{\partial x_2^2} + \dots + \frac{\partial^2 u}{\partial x_k^2}$$

and $u(P, Q, t)$ the fundamental solution of the heat equation $\Delta u - \frac{\partial u}{\partial t} = 0$, then for $P = Q$, Minakshi showed that in a neighbourhood of $t = 0$,

$$u(P, P, t) (4\pi t)^{k/2} \sim 1 + k_1 t + k_2 t^2 + \dots + k_n t^n + o(t^{n+1}).$$

The computation and geometric interpretation of the '*Minakshisundaram coefficients*' $k_1, k_2, \dots$ is still an open problem. In case $k = 2$, McKean and Singer showed that k_1 and k_2 are related to the curvature properties of the manifold. The latest work of Vijay Patodi* of the Tata Institute of Fundamental Research, shows what a cornucopia Minakshisundaram's work on the 'zeta functions' and eigen-value problems has proved to be.

Some years later, Minakshisundaram (1943) devised a method of arriving at the results of this paper with Pleijel, which did not appeal to Carleman's analysis, but which used the so-called 'method of iteration' of K. Yosida and his own method of using the fundamental solution of the heat equation. With a desire to finding the elusive 'functional equation' of his 'zeta function', Minakshisundaram began studying special cases of harmonics on homogeneous manifolds. However, as Bochner remarks, the integral representation of the 'zeta function' itself, when written as an infinite sum of residues at the poles, will be the functional equation. Such is the case, for instance, in the classical theory of L -series where one has a

*(See *J. Indian math. Soc.*, **34**, (1970), 269-286).

functional equation of Riemann type when the character is a so-called 'proper' character.

HIS FREQUENT VISITS TO THE U.S.A.

Minakshisundaram wrote several other papers during his stay at Princeton and returned to India in 1948 internationally recognised for his outstanding work. Early in 1950, the Andhra university promoted him to full professorship of Mathematical Physics, in recognition of his achievements. Minakshisundaram felt greatly encouraged and began working hard. He spent a few months at the Tata Institute of Fundamental Research where he collaborated with Chandrasekharan in the writing of the monograph on '*Typical Means*'. In 1950, he again went to Princeton shortly before the International Congress of Mathematicians at Cambridge, U.S.A. He visited the U.S.A. again in 1951 to attend a Symposium on '*Spectral Theory and Differential Problems*' at Stillwater, Oklahoma. After these brief interludes he settled down to work gathering around him a band of students working on problems of summability related to boundary value problems. In 1958 again, he undertook an educational tour of the U.S.A. and on his way back to India attended the International Congress of Mathematicians at Edinburgh, where he gave an address on 'Hilbert Algebras'.

During all these years, however, he published a number of papers on Fourier series in one and the several variables. In each one of these he elucidated one or other of some interesting aspects of Fourier series. He collaborated with K. Chandrasekharan, A. Pleijel, C. T. Rajagopal and Otto Szasz. With Chandrasekharan, above all, he wrote the beautiful monograph '*Typical Means*' which is a grand sequel to the classic Cambridge Tract '*The General Theory of Dirichlet Series*' by G. H. Hardy and M. Riesz. It is a source book for recent methods on problems of and results on summability by typical means.

HIS LAST DAYS

As years went by, Minakshisundaram found the atmosphere in an Indian University stifling for creative work. He desperately longed for a position at a Research Institute where he could work without let or hindrance and meet colleagues of high intellectual maturity. In 1954, he could invite to Waltair, though only for a few days, Professor Hans Maass of Heidelberg University who was at that time visiting the Tata Institute of Fundamental Research. Minakshisundaram was invited to attend the International Colloquium on '*Zeta Functions*' held at the Tata Institute of Fundamental Research, Bombay, in 1956. These contacts enabled him to write the note on the generalised unit sphere (Minakshisundaram 1955) where he generalised to the space of n -rowed complex symmetric matrices the notion of the usual Riemann sphere. This showed that he could not only learn new things easily but also do work on them. It emphasized also very strongly the need for contacts. Going back to Waltair, he easily succumbed to the dull and stifling atmosphere of university life. He wrote a few notes on his

first love-summability, but it was obvious that their standard was not that of the forties. His frustrations led to physical deterioration and a few years before his death he had a bad heart attack. He survived this and was glad to be appointed a professor at the newly created Institute for Advanced Studies at Simla. Here he was isolated but began working on a book on 'Spectral Theory' which, unfortunately he left unfinished. He planned once again to go to the U.S.A. but a second heart attack necessitated postponement. However, his heart ailment got worse and he passed away on August 13, 1968.

THE HIGH QUALITY OF HIS WORKS

Looking back on his achievements one cannot but be struck by their uniformly high quality, his great originality and his undoubted command over techniques of classical and modern analysis. Under more agreeable surroundings than those obtaining in an Indian university, he would, perhaps have done work of greater quality and no doubt of greater importance. Many a time he used to talk or muse about the great boost that the atmosphere at the Institute for Advanced Study at Princeton gave to his mathematical Research and at the same time revolutionised his thinking on Mathematics. It was not surprising that he longed for such surroundings during his later periods of acute mental depression.

Minakshisundaram liked to teach and tried hard to generate enthusiasm in his students and colleagues for mathematical research. He had uniformly high praise for the young Indian students in the universities who were and perhaps still are under what G. H. Hardy called '*an inefficient and inelastic educational system*'. He felt that, if even, under such an oppressive educational system, young men could aim at and achieve great heights, the results would be far more impressive under even slightly more propitious conditions. He had several research students working with him but unfortunately many of them either abandoned research after taking their doctor's degree or changed over to fields which offered greater job opportunities.

HIS HONOURS AND DISTINCTIONS

Minakshisundaram was an extremely simple man, a little bit of a retiring type. He was a valued Member of the Indian Mathematical Society from 1943 and attended, for several years, the annual meetings of the Society. He was elected President of the Indian Mathematical Society in 1967 but could not accept it due to ill-health. He was elected Fellow of the National Institute of Sciences of India (now the Indian National Science Academy) in 1958 and attended the Indian Science Congress. He was keenly interested in reform of mathematical education but he found that the (non-scientific) problems were too formidable for a man with limited influence. His passing away is a great loss to Indian mathematics and to his several friends who had known him intimately and loved him.

K. G. RAMANATHAN*

*The author is greatly indebted to Fr. C. Racine and C.T. Rajagopal for many biographical details and reminiscences and for the complete list of Minakshisundaram's publications.

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RUSTOM JAL VAKIL

(1911-1974)

Elected F.N.I. 1959

EARLY LIFE AND EDUCATION

RUSTOM JAL VAKIL was born in Bombay on 17th July 1911. The only son of Dr. Jal and Jerbanoo Vakil, he had his school education at the Bharda New High School, Bombay. His father was a busy general medical practitioner and Rusi was largely influenced, in his early years as a child, by his mother who was a lady of drive and determination. This is borne out by an incident when the young boy was seeking admission to school. A few weeks before joining the New High School, he was taken by his mother, through the insistence of friends, to the principal of an English school, which was the pride of the well-to-do classes in those days. During the entire interview for admission which lasted about half-an-hour, and which was more in the nature of a legal cross-examination than a search for information, Mrs. Vakil and the young boy were kept standing, while the English principal was comfortably reposed in a posh arm-chair. After the interview when the principal pronounced his final verdict, "I am afraid your son is not good enough for our school." Mrs. Vakil came up with a parting shot that left an enduring impression on the young lad's mind—"I am not sorry my son fails to get admission in your school. He might have picked up the bad manners of the principal who did not even have the courtesy to offer a seat to a lady".

HIGHER EDUCATION IN U.K.

After receiving his early college education at the Elphinstone College and Royal Institute of Science, Vakil proceeded to England, accompanied by his mother, having already lost his father while still at school. In London he secured admission at the St. Thomas' Hospital Medical School from where he graduated in the year 1934. During his medical college career, he won 27 prizes including the '*Mead, Seymour, Graves Toller, Wainwright and Lalkaka Medals*' of the London University. Dr. Vakil passed his M.R.C.P. (Lond.) examination at the young age of 24 years in 1936 followed by M.D. of the same University in 1937 both at first attempt.

MEDICAL CAREER IN INDIA

Returning to India in 1938, Dr. Vakil started consulting practice. His exceptional qualities made themselves apparent and he soon built up a large private practice. He was appointed Asst. Hon. Physician to the J.J. Hospital and Grant Medical



Rustan Sal Vakil
—

College and after a short while took up a similar appointment at the K.E.M., Hospital and Seth G.S. Medical College. He was a very popular teacher. Students used to flock to Dr. Vakil's clinics not only because of his simple style of teaching but also because of his wit and humour.

Dr. Vakil was an astute clinician and believed that *"although instrumental aid may be indispensable to cardiac diagnosis today, they should be used to supplement clinical methods of examining the patient"*. And he quoted Sir John Ryle, *"Eyes without the microscope, ears without stethoscope and wits without the help of chemistry and radiology can often carry us a long way."*

As a clinician, Dr. Vakil impressed everyone by his competence and efficiency. He had a delightful charm of manner. During all the years of practice, his reputation enforced by his writings grew and he was perhaps the most sought after cardiologist in India. In fact, Dr. Vakil was one of the first to introduce specialisation in cardiology in this country and restricted himself to this branch of medicine.

CONTRIBUTIONS TO SCIENTIFIC KNOWLEDGE

During Dr. Vakil's eventful career, his pen was fully employed and there must be very few clinicians to whom writing came so easy. His publications made a long list, but his most notable contribution was his historical paper on the use of *Rauwolfia serpentina* for the treatment of high blood pressure which appeared in the *Br. Heart J.*, in 1949. Following its publication, many millions of patients all over the world began to be treated for hypertension with this drug and efforts made to synthesize and employ therapeutically many other drugs for the treatment of this malady.

Reference to Dr. Vakil's research in this direction was made during the 85th Annual Meeting of the American Public Health Association in 1957.

"In a historical paper on the use of 'Rauwolfia' in hypertension, which appeared in the British Medical Journal in 1949, he summed up 10 years of careful conscientious work that he had carried out personally, added the opinion of some 50 other physicians who had worked with 'Rauwolfia' in hypertension and produced a document which brought this drug finally and decisively into Western medicine. The 'Rauwolfia' alkaloid, reserpine, was found to be a powerful tranquillising agent and identified as a valuable addition to psychiatric therapy. But more than that, it opened an entirely new method of therapy of mental disorder itself. For his part in this epoch-making advance, the American Public Health Association is proud to present this Albert Lasker Award".

Dr. Vakil was the first Asian to receive the International Albert Lasker Award. The Lasker awards are given by the Albert and Mary Lasker Foundation to individual and groups for "outstanding contribution in research related to diseases which are the main cause of death and disability and for distinguished service in the field of public health administration". A souvenir issued on the occasion of the presentation of the awards had this to say: *"The story of 'Rauwolfia serpentina' is an example of a block in medical communication that in retrospect seems hard to understand. This drug had been used in ancient Ayurveda medicine in India for hundreds*

of years and had been the subject of modern scientific research in India since at least 1731, it had been repeatedly reported as a psychiatric and anti-hypertensive therapy in the technical journals of India and these publications were available in scientific libraries everywhere. Yet, while innumerable fruitless leads were being followed by Western medicine, this important one was overlooked until attention was finally focussed on it by Dr. Vakil".

The introduction of *Rauwolfia* to Western medicine was described by the then Surgeon-General, U.S.A. as a "trail-blazing and an epoch-making discovery", while Dr. Vakil was referred to at the time of announcement of the Award ceremony of the Lasker Foundation as the 'Father of Indian Cardiology' and 'Father of *Rauwolfia*'.

There is further reference to Dr. Vakil's contribution in this direction in the 'Autobiography of Science' by Moulton and Schiffrs (John Murray, London, 1960):

"New and more successful lines of treatment for both heart disease and mental or emotional ailments quickly arose from the introduction of an ancient folk remedy of the Far East, *Rauwolfia serpentina*, also known as Indian snake root, into Western medicine. Much of the credit for this goes to an Indian physician, Rustom Jal Vakil, of the Cardiovascular Department of the King Edward VII Memorial Hospital, Bombay, India".

Dr. Vakil had several firsts to his credit. He was the first to carry out large scale statistical studies on the incidence of various types of heart disease especially coronary heart disease. He published a survey of 20 years study of several thousand cases of isochemic heart disease, including 25,000 cases of coronary thrombosis observed personally.

Dr. Vakil was the first to use the term 'pre-infarction syndrome'. It was born out of a study and description of 360 cases of coronary heart diseases.

In response to an invitation from the American College of Cardiology, he submitted an epidemiological survey of cardiovascular disease in India based on the study of 15,000 cardiac patients.

Dr. Vakil was responsible for the study and publication, once again for the first time in this country, of normal electrocardiographic standards and normal blood pressure standards for Indian subjects with special reference to young age groups. He also published a large statistical study of 1860 cases of heart disease, with individual studies of different types of affections such as hypertensive, syphilitic, coronary, pulmonary and rheumatic forms of cardiovascular maladies.

Besides the 'pre-infarction syndrome,' we owe to Dr. Vakil some entirely new clinical entities in medical science, namely 'hexalogy of the heart', 'giant cell arteritis in aortic regurgitation', 'transitory pulsation in coronary thrombosis', 'gummatous forms of rat-bite fever' and 'subacute pulmonary oedema'.

Being much in favour of clinical diagnosis, Dr. Vakil introduced a new classification for abnormal heart rhythms; and being aware of the increasing incidence of coronary heart disease, he made practical suggestions for starting a drive against coronary or atheromatous heart disease.

In his writings, Dr. Vakil suggested several new classifications for common

clinical conditions including anterior thoracic pain, left supramammary pain, congenital heart disease, heart murmurs, and of blood pressure phenomena.

Following his success with *Rauwolfia*, Dr. Vakil got interested in another ancient Indian plant *Nardestachya jatamanshi*, and wrote about its utility in the treatment of neuropsychiatric disorders.

Dr. Vakil had a fluency of speech which few could match and this combined with his sense of humour, earned him the reputation of being one of the most gifted and impressive public medical speakers.

A series of articles appeared in the '*Illustrated Weekly of India*' in 1964-1965 on 'The Medical Legacy'—a history of ancient Indian medicine and these were widely acclaimed.

AWARDS & HONOURS

Besides being the first Asian to receive the '*Lasker award*' (the other being Dr. Har Gobind Khorana who won the award 15 years later), Dr. Vakil was recipient of numerous honours, awards, prizes and medals both in this country and abroad. These included the '*Padma Bhushan*' by the President of India (1958), the first '*Dr. B. C. Roy Award*' of the Indian Medical Council for promoting cardiology in India (1969); the '*Shanti Swarup Bhatnagar Award*' of the Council of Scientific & Industrial Research for "outstanding contribution to Cardiology (1965)" and the first '*Dhanwantri Award*' (1973) for being "the most outstanding medical personality of the year in India".

Dr. Vakil was an elected Fellow of over 20 International and National medical and scientific bodies, including the Royal College of Physicians of London, the American College of Cardiology, the American College of Physicians and the Indian National Science Academy. He was one of the four Indian clinicians to figure in the American "*Register of International Notables*". He was also a Fellow of the American Geriatrics Society; the Royal Society of Health; American Association for Advancement of Science; Royal Society of Tropical Medicine; Royal Society of Arts; the Royal College of Physicians, Glasgow; International College of Angiology; American Public Health Association; Royal Society of Medicine; International Academy of Chest Physicians and Surgeons; Indian Academy of Sciences; Royal Geographical Society; College of Physicians and Surgeons; Bombay; and Founder Fellow of the American College of Post-graduate Studies. He was a Member of the American Heart Association and a Director of All India Heart Foundation, New Delhi.

Dr. Vakil was Governor of the Western India Chapter of the American College of Chest Physicians; Co-ordinator of the All India Heart Foundation; Past-President of the Cardiological Society of India; Past-President of the Bombay Medical Union; Patron of the Society for the Prevention of Heart Disease, Bombay, and a Trustee of the Wadia Institute of Cardiology, Poona.

Dr. Vakil was invited from all over the country to deliver orations and lectures. He was Sir Nilratan Sircar Lecturer for 1957 and Dr. S. N. Bhansali Lecturer of Calcutta and Prizeman of the Bombay Medical Union in 1960. He gave the

Arustha Memorial Lecture in 1962 in Hyderabad. He was Foundation Lecturer for the '*Maharashtra Medical Journal*', Poona in 1965 and the Netaji Bose Orator at Gwalior in 1966. He was chosen as the Vythilingam Orator at Vellore in 1967 and the Edward Pinto Orator at Secunderabad in the same year. Dr. Vakil was the Awalanada Das Memorial Lecturer of the Cardiological Society of India in 1970. He was awarded the '*V World Congress of Cardiology Souvenir Award*' given by the Cardiological Society of India in 1971.

Dr. Vakil besides being associated with the K. E. M. Hospital, Bombay, held a number of hospital appointments over the years. He was a Visiting Cardiologist to the Sir Nanavaty Hospital, the Sir J. J. Group of Hospitals, the Bombay Hospital, the Parsee General Hospital, the J. N. Railway Hospital and the Bhatia General Hospital.

HIS PUBLICATIONS

Besides being the author of several contributions to medical literature and Editor of more than one medical journal, he was the author of several books on cardiology and other subjects used by students and doctors. His book '*Clinical Diagnosis*', a text book of symptoms and signs, is very popular with students in several countries and was well reviewed in foreign journals. He was solely responsible for editing the first '*Text-Book of Medicine*' by Indian authors published by the Association of Physicians of India. The text book on '*Diagnosis and Management of Medical Emergencies*' was recommended by Lord Rosenheim, President of the Royal College of Physicians of London.

Dr. Vakil did not restrict himself to writing for the benefit of the medical profession, but used his wide reading to the advantage of the layman also.

"*The Romance of Healing and other Essays*" were based on lectures and addresses delivered by him and articles contributed to the '*Illustrated Weekly of India*' and other periodicals. In this book, a wide variety of medical and allied subjects was discussed in simple and lucid style, the author adopting a historic perspective in his presentation. The essay 'The Physician in Shakespeare' has an evaluation of Shakespeare's 37 plays in relation to medical references and descriptions.

"*Our Glorious Heritage*", commended by the late President of India, Dr. S. Radhakrishnan, to the 'Cultivated Reader', gave a brief history of medicine, particularly India's contribution to the art and science of healing.

The book "*Heart in Health and Disease*" contained information about the structure, functions, behaviour and accomplishments of the human heart, under physiological and pathological conditions and in his usual easy style, the author presented useful information about the virtues and vagaries of the human heart.

HIS QUALITIES

Rustom Jal Vakil was a warm-hearted, friendly and modest man who loved his profession. He was completely devoid of all pomposity and affectation. His character and personality, unspoilt by worldly success and renown, combined

with his vast clinical knowledge and wisdom went to make him the ideal physician whose advice was sought by patients in all walks of life. Although never absconding from his personal natural dignity, he was fond of good food and convivial company. Dr. Vakil's two most favourite pastimes were music and dancing. He had a special knack of telling a good joke.

Dr. Rustom Vakil was generous at heart. He established by donation the 'Dr. R. Jal Vakil Gold Medal' for the All India Heart Foundation and the 'Mrs. J. N. Vakil Medal and Lectureship' in Cardiology for the Association of Physicians of India as also the 'Dr. R. Jal Vakil Lectureship' of the Bombay Medical Union.

ESTABLISHMENT OF THE VAKIL INSTITUTE OF CARDIOLOGY

A few months before his death, Dr. Vakil saw his long-cherished wish come true in the establishment of the Vakil Institute of Cardiology and Research Centre at the K. E. M. Hospital, Bombay, to which he gave a personal contribution of Rupees one lakh. A further sum of four lakhs was donated by friends and admirers of Dr. Vakil. The Institute and Research Centre was inaugurated by the Governor of Bombay at the K. E. M. Hospital on 28th September, 1974. Meant to pursue the activities in Cardiology founded by Dr. Vakil, the Institute is devoted to the prevention, early detection and treatment of diseases of the heart.

HIS UNTIMELY DEATH

The untimely death of Dr. Vakil in Bombay on 20th November, 1974 from aortic dissection and myocardial infarction stunned many who knew him and his great qualities and achievements. It is to be hoped that the qualities which he so notably exemplified will continue to enrich the profession of medicine so that while retaining the scientific background it may not cease to be an art. Dr. Vakil walked gracefully through life and his premature death has left a void in the field of cardiology that is difficult to fill. Dr. Vakil is survived by his wife Jeroo.

ASPI F. GOLWALA

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VIKRAM SARABHAI

(1919-1971)

Elected F.N.I. 1963

DR. VIKRAM AMBALAL SARABHAI, Fellow of the Indian National Science Academy and the main architect of Indian Space Research and Technology, passed away on 31st December 1971. He was truly a rare combination of an innovative scientist, a progressive industrialist, a humanist and a visionary. Professor Bruno Rossi of the Massachusetts Institute of Technology, a pioneer in Cosmic Ray Physics, writes in his article on Vikram Sarabhai the following appreciation :

“Vikram Sarabhai was truly one of the most remarkable human beings I have ever known. He could engage simultaneously in a number of different activities, each sufficiently demanding to fill the life of a lesser man without showing any sign of stress or allowing the preoccupation of his work to effect the warmth of his personal relations. Science was clearly at the centre of his interests. It is perhaps an idle question to ask oneself whether he derived more satisfaction from the pursuit of science as a purely intellectual endeavour or from its use as a powerful instrument to better the condition of mankind”.

EARLY YEARS

Sarabhai had his early education in a private school, Retreat, organised by his parents on Montessori lines. The school had imaginative teachers, a workshop and an atmosphere of scientific curiosity. This probably injected into young Sarabhai the seeds of scientific curiosity, ingenuity and creativity. For his collegiate education, he was sent to St. John's College, Cambridge, England, in 1937. Here at 18, he took his Natural Science Tripos with Physics and Mathematics in 1940 and began work on problems on Nuclear Physics. With the beginning of World War II, he returned to India and joined the Indian Institute of Science, Bangalore as a Research Scholar under Professor Sir C. V. Raman. He chose Cosmic Rays as his subject and personally built the necessary equipment with which he took measurements at Bangalore, Poona and Apharwat in the Kashmir Himalayas. In 1945, at the end of World War II, he returned to Cambridge and took the Ph.D degree on his thesis, *‘Cosmic ray investigations in tropical latitudes’*. He was awarded the degree in 1947.

ESTABLISHMENT OF PHYSICAL RESEARCH LABORATORY AT AHMEDABAD

Even in 1943, Vikram had plans to start a Laboratory in Ahmedabad. He talked with Dr. K. R. Ramanathan, who was then in the Indian Meteorological Department, about his tentative plans.

While starting the new Institution, Sarabhai discussed his plans with different colleagues and friends and, having evolved the broad objectives, collected a small group of dedicated bright scientists and technicians and started work. In Retreat, he already had a laboratory for cosmic rays with a skeleton staff. Aware of Dr. K. R. Ramanathan's interest and reputation in atmospheric physics, he consulted him regarding the establishment of the laboratory and also asked if he could join him. Dr. Ramanathan agreed to join immediately after his retirement from India Meteorological Department in 1948.

The combination of Sarabhai and Ramanathan was remarkable, Ramanathan with his keen interest on Atmospheric Physics, Geomagnetism and Solar-Terrestrial Relationships and a vast experience on Atmospheric Dynamics, and the younger Sarabhai with his interest on Cosmic Rays and a fund of unlimited enthusiasm.

The Physical Research Laboratory at Ahmedabad was established with the assistance of the Ahmedabad Education Society, and the Karmakshetra Educational Foundation which was founded by his parents Shri Ambalal Sarabhai and Shrimati Saraladevi Sarabhai. This was in November 1947. Assistance of the CSIR (under S. S. Bhatnagar) and of the Department of the Atomic Energy (under H. J. Bhabha) were also obtained.

The Laboratory started work in November 1947 in a few rooms in the M. G. Science Institute of the Ahmedabad Education Society while Sarabhai was looking for suitable land. Sarabhai shifted the small workshop and equipment from his home to this building along with a small staff of competent technicians and, scientists. Chief among them was Shri G. P. Joshi who later organised the Police Wireless Organisation in U.P.

The predominant role that Dr. Sarabhai played in the building of this institute can be seen from this statement of Dr. Ramanathan:

'I began to appreciate the multi-dimensional character of his personality only after I joined at Ahmedabad. Besides setting himself the task of building the PRL from scratch, he had also undertaken the responsibility of establishing the Ahmedabad Textile Industry Research Association (ATIRA) in which the industry and the Government would share costs'.

In the early days of the PRL, the scientific activities were in two broad lines, one under Dr. Sarabhai dealing mainly with the time variations of cosmic rays, and the other under Dr. Ramanathan in the areas of ionospheric and upper atmospheric physics. Sarabhai set up a permanent recording station at Ahmedabad and subsequently established two more stations near the geomagnetic equator at Kodaikanal and at Trivandrum which began operation in 1951 and 1955 respectively.

PERSONAL RESEARCH ON COSMIC RAY TIME VARIATIONS

Sarabhai's primary research activity in the fifties and sixties concerned the time

variations of cosmic rays. The extent to which they were extraterrestrial in origin was at that time unclear. By collecting and critically analysing his own observations as well as those of other scientists, Sarabhai and his co-workers concluded that meteorological effects could not entirely account for the observed daily variations of cosmic rays, and that these effects could be estimated and corrections applied to cosmic ray time variations. They found that the residual variations were appreciably wide and global, and were related to variations in solar activity.

Sarabhai's initial belief was that the observed anisotropies were due to a continuous but variable emission of the cosmic ray particles from the sun. By the middle fifties, however, there was increasing evidence that interplanetary space was filled with magnetized plasma whose conditions were controlled by the sun and he felt that the anisotropies were far more likely to be due to modulation by interplanetary magnetic field of an originally isotropic radiation entering the solar system from interstellar space.

Around this time, E. Parker suggested existence of a continuous outflow of a steady plasma wind flowing out from the rotating sun stretching the magnetic field lines into the shape of Archimedes spiral. The directional studies of Cosmic Rays by Sarabhai and his students showed that this solar wind came from a direction inclined at about 45° to the East of the Zenith and could be explained if the solar wind co-rotated with the sun and took the form of the spiral in the interplanetary space.

If the observed cosmic ray anisotropies were to be regarded as modulation effect to the solar wind, then it opened up a new vista of research in solar and interplanetary physics. This was not lost on Sarabhai. In a review at that time Sarabhai commented:

"We now accept the existence of large changes of primary intensity. We have good reason to believe that many of these changes represent modulations of primary intensity occurring at some distance from the earth. The changes provide a new and valuable tool to study electromagnetic fields and distribution of matter in interplanetary and interstellar space. There appears a possibility of explaining the changes in terms of the chaotic turbulent condition of matter in such space. The changes also furnish insight into Solar Physics".

The problem of identification of the physical processes responsible for these anisotropies assumed great significance.

In his appreciation, Bruno Rossi commenting on this aspect of work of Sarabhai and his colleagues stated:

"Before any progress in this direction could be achieved, it was necessary (i) to have a reliable method for taking into account the effect of geomagnetic bending upon the directions of the arrival of Cosmic Ray particle upon the earth and (2) to obtain experimental data on the configuration of the magnetic field and on the plasma parameters in interplanetary space. The first requirement was fulfilled in the middle sixties by the painstaking

computation of U. R. Rao and McCracken which resulted in the determination of acceptable 'cone' for each of the cosmic ray recording stations. The acceptance cone depends not only on the geographical location of the station but also on the band of primary energies to which the recording is sensitive. In the meantime with the advent of space age artificial satellites and deep space probes provided with magnetometers and plasma measuring instruments had undertaken a direct exploration of interplanetary space, thus fulfilling at least partially the second requirement. These experiments confirmed a qualitative validity of Parker's model and provided direct information on the direction of the magnetic field lines near the earth. Eventually, they also detected the rotating shocks predicted by Sarabhai".

In those works on Cosmic Rays, Sarabhai gathered around him a number of bright young scientists who, in later years, attained reputation of their own in a wide variety of activities. These include: V. D. Desai, R. P. Kane, P. D. Bhavsar, T. S. G. Sastry, Satya Prakash, and U. R. Rao.

THE INTERNATIONAL GEOPHYSICAL YEAR AND THE BEGINNING OF INDIAN SPACE RESEARCH

The first opportunity in the post-independence period for India to participate in a major International Scientific Programme occurred during the International Geophysical Year and the International Geophysical Co-operation of 1957-58. The responsibility for organising this programme in India was given to a National Committee of which the late Sir K. S. Krishnan was Chairman. The principal areas included: Ionosphere, Cosmic Rays, Solar Activity, Geomagnetism, Meteorology and Oceanography. Dr. Sarabhai was member for Cosmic Rays. The Indian programme for the IGY seems, in retrospect, to have been one of the most significant ventures, which provided opportunities to a large number of young scientists to work on a gigantic scientific programme at the international level. Sarabhai's contribution to this programme was particularly important because cosmic rays, ionosphere and meteorology were at that time the three most extensive scientific programmes of the country and also because it exposed him to the new *Vistas* of Space Science that opened up during the IGY with the launching of Sputnik-1 in 1957. India's programme for Space Research began in a very modest way at the same time. Two major events were the installation of a Baker-Nunn Camera at Nainital (under Dr. Vainu Bappu, the then Director of the U.P. State Observatory) and the effort to build atmospheric density models at NPL using satellite drag observations.

FORMATION OF INCOSPAR—RAPID GROWTH OF SPACE RESEARCH

The Indian National Committee for IGY looked after the modest efforts in space science in this country until February 1962 when the Department of Atomic Energy created the Indian National Committee for Space Research (INCOSPAR).

Dr. Sarabhai was appointed Chairman of this new committee with Dr. K. R. Ramanathan, the present author and a few others as Members. This Committee was entrusted with the responsibility of developing space research in India for peaceful purposes.

First, Dr. Sarabhai decided to set up a Rocket Launching Station in the country. With support from Dr. H. J. Bhabha, he selected Thumba (near Trivandrum) on the Arabian Coast as the most appropriate place for this range. The choice was determined by the fact that Thumba is very close to the magnetic equator where anomalies occur in Geomagnetism, Ionosphere, and Cosmic rays of considerable scientific interest. The Range was set up with the collaboration of the Kerala Government and within a very short time the first rocket (A Nike-Apache provided by NASA) was launched with sodium vapour payload on 21 November 1963. This was a remarkable achievement, since it involved not only the acquisition of the land but also the rehabilitation of the fishermen who occupied that area, the selection and recruitment of personnel setting up of roads and buildings, communication links, launch pads and other necessary facilities for carrying out rocket launchings. After this inaugural flight, Range facilities were expanded rapidly. The Range currently has launchers for small rockets for meteorological studies such as Menaka, Judi-Dart, M-100 and SKUA-I, and the larger rockets going into the atmosphere, such as Boosted-Areas, RH-300, Centaur, Petrel, Skua II, Nike-Apache, Nike-Tomahawk and RH-560.

Between 1961 and 1966, Sarabhai took the following major steps:—

- 1) The Physical Research Laboratory, Ahmedabad, was expanded as the Headquarters for Space Activities.
- 2) The Space Science and Technology Centre (SSTC) was set up near TERLS in Thumba and work started on rocket materials, propellants, fabrication of rockets and testing systems etc. Arrangements were made with Sud Aviation, France, to fabricate two-stage Centaur rockets in India under licence.
- 3) Agreement was reached with UNDP to establish an Experimental Satellite Communication Earth Station (ESCES) at Ahmedabad.

In 1965, the UN General Assembly gave recognition to TERLS as an International Facility. The formal dedication of TERLS to UN took place in February 1968 and was made by Prime Minister Indira Gandhi.

With the sudden passing away of Dr. Homi Bhabha in 1966, in an air accident, Sarabhai was asked to take over as Chairman of the Atomic Energy Commission and Secretary of the Department of Atomic Energy in May 1966. Thus, he became responsible for both Atomic Energy and Space Research in the country.

Like Bhabha, Sarabhai was a great believer in the application of science to the practical developments of India. He saw in Space Research not merely a glamorous, exotic, exciting, new form of science but a great opportunity to harness space science to important tasks in the country in the fields of communication, education, meteorology, geodesy, remote sensing, etc.

The ESCES, which became operational in 1967, provided an opportunity for

introducing the elements of space communication in the country. The training imparted and the experience gathered at this Centre provided the basis for subsequent installation of the International Satellite Communication Centre for the Overseas Satellite Communication Centre at Arvi near Poona which has since been providing commercial telephone circuits for overseas traffic.

Dr. Sarabhai was elected as Scientist-Chairman of the UN Conference on Exploration and Peaceful Uses of Space Science held in Vienna in August 1968. At this meeting, he commented (*vide Nuclear India*, Sept. 1968, p.6):

"I have asked myself the question why is India one of the most expensive poor countries? I could observe two important factors. First that since developing nations by definition start from a low economic base, their incremental growth, large as it might be when expressed percentwise, is intrinsically small, compared to the incremental annual growth even of much smaller economically advanced nations. Thus, a developing nation following a step-by-step approach towards progress is landed with units of small size, which do not permit the economic deployment of new technologies....."

A positive approach out of this predicament seems to lie in finding solutions where the particular disadvantage of developing nations, which is that they have little to build on, is made an asset rather than a liability. I suggest that it is necessary for them to develop competence in advanced technologies and to deploy them for the solution of their own particular problems not for prestige but based on sound technical and economic evaluation involving commitment of real resources. They would most likely discover that the traditional approach of planning to provide things like electric power or telecommunication services for national infrastructure, based on projections of growth from past experience leads to a dead end.....

Developing nations which have a large area and big population, such as India, have the possibility of effectively utilizing space communications systems for national needs. Compared to advanced nations such as the U.S.A., Canada and U.S.S.R., they have indeed an advantage through not having an existing major investment in older technologies.....

There are these who preach as guardians of the economic well being of the developing nations that they must proceed step by step following the same process by which the nations themselves progressed. One is often told that such and such a thing is too sophisticated to be applied. This approach disregards what should perhaps be obvious, that when a problem is great, one requires the most effective means available to deal with it."

SATELLITE INSTRUCTIONAL TELEVISION EXPERIMENT (SITE)

Another major achievement with which Sarabhai was associated is the now-famous SITE. The programme has ended after a period of one year from July 1, 1975 to 31st July 1976. In this, TV programmes particularly tailored to Indian villagers were received by 2,400 specially augmented TV receivers in six clusters. The programme was the result of negotiation between Sarabahi and NASA. The impact of this SITE programme is still to be judged, but for the first time,

an entirely modern and sophisticated technology was brought to provide education, agriculture and family planning to some of the remotest villages in the country. The responsibility for providing the augmented TV receivers and the ground support, including the TV programme, was taken up by India. This has been carried out with efficiency and reliability by the Space Application Centre, under the supervision of Dr. Yash Pal.

The SITE was looked upon by Sarabhai as the beginning of a largescale satellite direct broadcast programme in the country which should gradually be expanded with proper coordination with groundbased transmitters, to cover eventually all of the 5,60,000 villages in India.

Another important space project initiated by Sarabhai, and now a reality, was the bold undertaking of fabrication and launching of an Indian satellite. He realised that if space research was to be effectively harnessed for nation development, it must develop an indigenous capability for satellite launching, ranging from low-orbiting to synchronous levels. He therefore set in motion a project on satellite fabrication and the development of the necessary launching vehicles. Aryabhata I, launched in 1975 from a Russian Cosmodrome, and now in orbit, is a result of this planning.

SARABHAI AS EDUCATIONIST

Apart from the students he trained in Cosmic Rays some who now occupy important scientific positions in India and abroad, Sarabhai took keen interest in developing and encouraging scientific temperament in the young. With this end, he established a "Community Science Centre" at Ahmedabad under the auspices of the Nehru Foundation for Development. The Centre provides laboratory facilities, and college students are encouraged to ask questions and do experiments under the supervision of trained scientists.

HONOURS AND DISTINCTIONS

Dr. Sarabhai received many honours and awards. He received the '*Shanti Swarup Bhatnagar Medal* (1962).' He was elected Fellow of the National Institute of Sciences of India (now Indian National Science Academy) in 1963. He was President of the Physics Section of the Indian Science Congress in Cuttack in 1962 and the Indian Geophysical Union for 1970-71. He was awarded Padma Bhushan in 1966, and Padma Vibhushan posthumously in 1972. He was a Member of the International Council of Scientific Unions in 1966, Chairman of the Panel of Experts and Scientific Chairman of the UN conference on the '*Exploration and Peaceful Uses of Outer Space*' in 1968, President of the 14th General Conference of the International Atomic Energy Agency (Vienna, 1970) and Vice-President, Fourth UN conference on '*Peaceful Uses of Atomic Energy* (1971).'

Sarabhai died in his sleep on 31st December, 1971, in a hotel on his beloved Kovalam Beach near the Thumba Rocket range after a hard day's work with Thumba scientists and engineers. That the work he started was not in vain is

evident from the spectacular strides made by space technology in this country in the last few years.

ACKNOWLEDGEMENT

In the preparation of this memoir, much use has been made of the following two publications :

1. *Vikram Sarabhai—Selected Scientific Papers*, PRL, 1974.
2. *25 Years of PRL*, PRL.

A. P. MITRA

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